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BONUS! Astronomy's 2010 Guide to the Night Sky

January 2010

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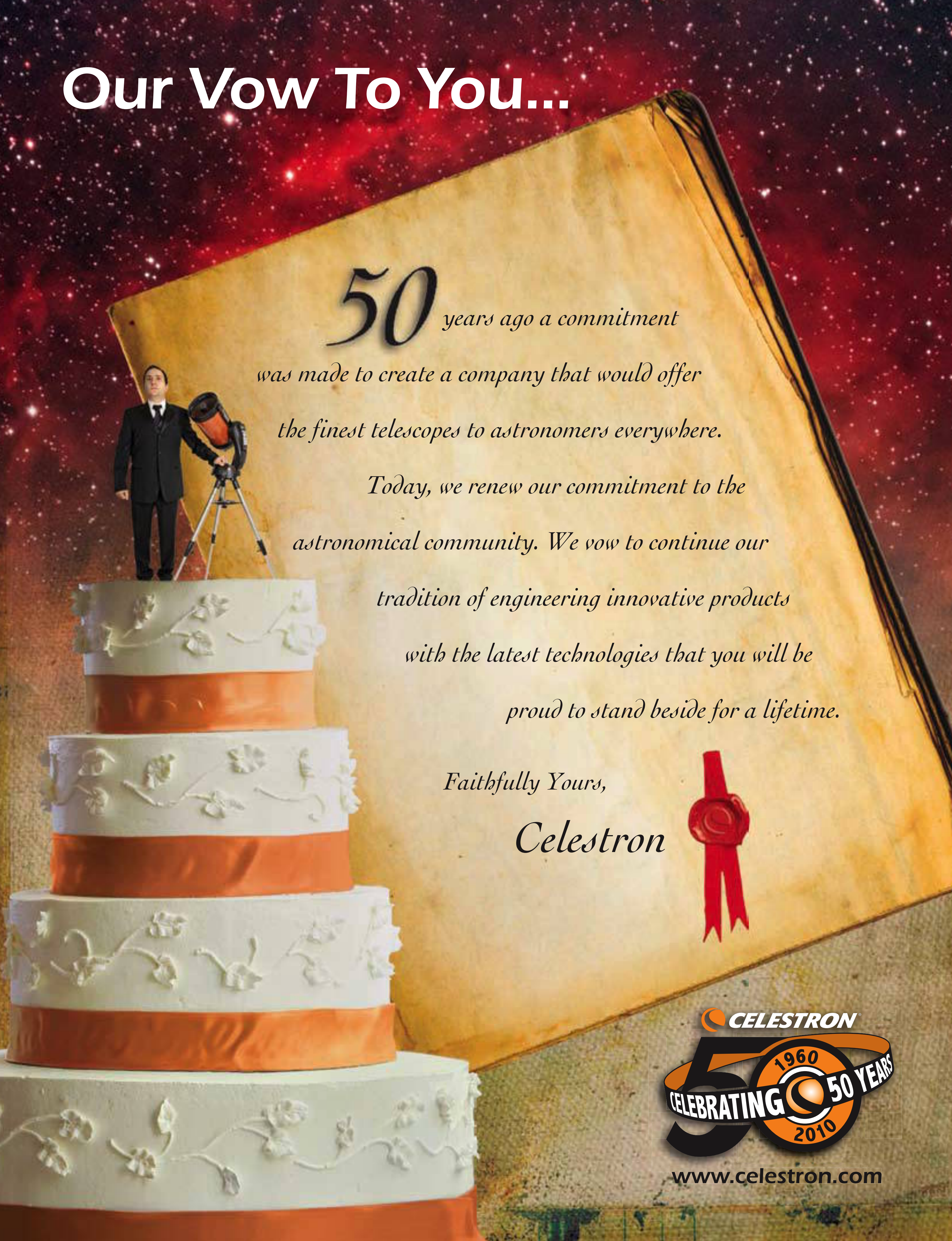

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Tackle This Intriguing Cosmic Question with a Theoretical Physicist at the California Institute of Technology

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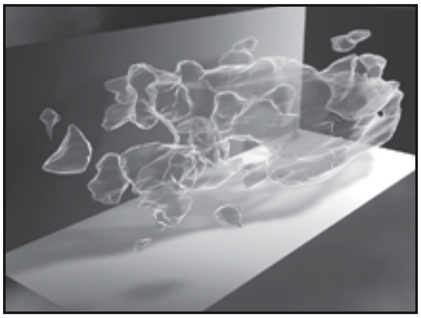

The distribution of dark matter in the universe

NASA, ESA and R. Massey (California Institute of Technology).

About Your Professor

Professor Sean Carroll is a Senior Research Associate in Physics at the California Institute of Technology. He received his Ph.D. in Astrophysics from Harvard, did postdoctoral research at MIT and UC Santa Barbara, and taught at the University of Chicago. He has received research grants from NASA, the U.S. Department of Energy, and the National Science Foundation. In 2006 he was awarded the Arts and Sciences Alumni Medallion from Villanova University.

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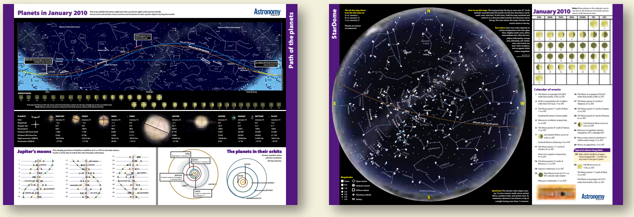

Path of the planets and StarDome.

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This Month in *Astronomy*

by David J. Eicher

Editors dedicate *Astronomy*'s new observatory

On September 17, at Rancho Hidalgo near Animas, New Mexico, Publisher Kevin Keefe, Contributing Editor David Levy, and I joined a group of some 50 people to dedicate the magazine's new observatory and to dedicate Pluto discoverer Clyde Tombaugh's personal telescope in its new location.

We will use the new observatory for imaging deep-sky objects and planets, as well as Hydrogen-alpha imagery of the Sun. Editors will control imaging remotely from our offices in Waukesha, Wisconsin. The observatory contains a 14-inch Schmidt-Cassegrain telescope and a refractor for solar imaging, both fitted with CCD cameras and a solar filter on the refractor. You will soon begin to see images made with both telescopes in the magazine and on our web site.

The evening of September 17 was a proud one for us. We coupled the observatory's dedication with the first-light event for Tombaugh's reassembled 16-inch telescope, which stands adjacent to the magazine's observatory.

Patsy Tombaugh, Clyde's widow, poses in front of the 16-inch telescope. David J. Eicher

We lost Clyde 12 years ago, but his widow, Patsy Tombaugh, arrived on the scene for the dedication. At age 97, she is still going strong, and she recounted many stories of Clyde.

Several friends and notables gave short talks, beginning with Rancho Hidalgo's developer, Gene Turner. Then came an entertaining remembrance of Clyde by David Levy, a contributing editor of *Astronomy* and the man who wrote the definitive biography of Tombaugh, *Clyde Tombaugh: Discoverer of the Planet Pluto*. I then spoke briefly about the *Astronomy* Magazine Observatory and my fondness for Clyde, and Patsy Tombaugh closed with a few words. Next, we tried to observe the sky, which was not cooperating due to the monsoon season.

***Astronomy* magazine** Editor Dave Eicher, Contributing Editor David Levy, and Publisher Kevin Keefe pose with Clyde Tombaugh's rededicated telescope. David J. Eicher

The next night, we went after the Sagittarius mainline, the arch of bright deep-sky objects from the galactic center northward. We observed many targets, although some hopping back and forth around the sky was necessary due to dark clouds that washed over parts of the sky.

The view of the Andromeda Galaxy and its satellites was incredible, the nucleus glowing brilliantly and the dust lanes sharply defined. In the end, I think Kevin was satisfied with his first night of dark-sky, big-scope viewing.

You can see the full image gallery of the dedication ceremony in our Online Reader Gallery at www. Astronomy.com/readergallery.

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 38, Number 1

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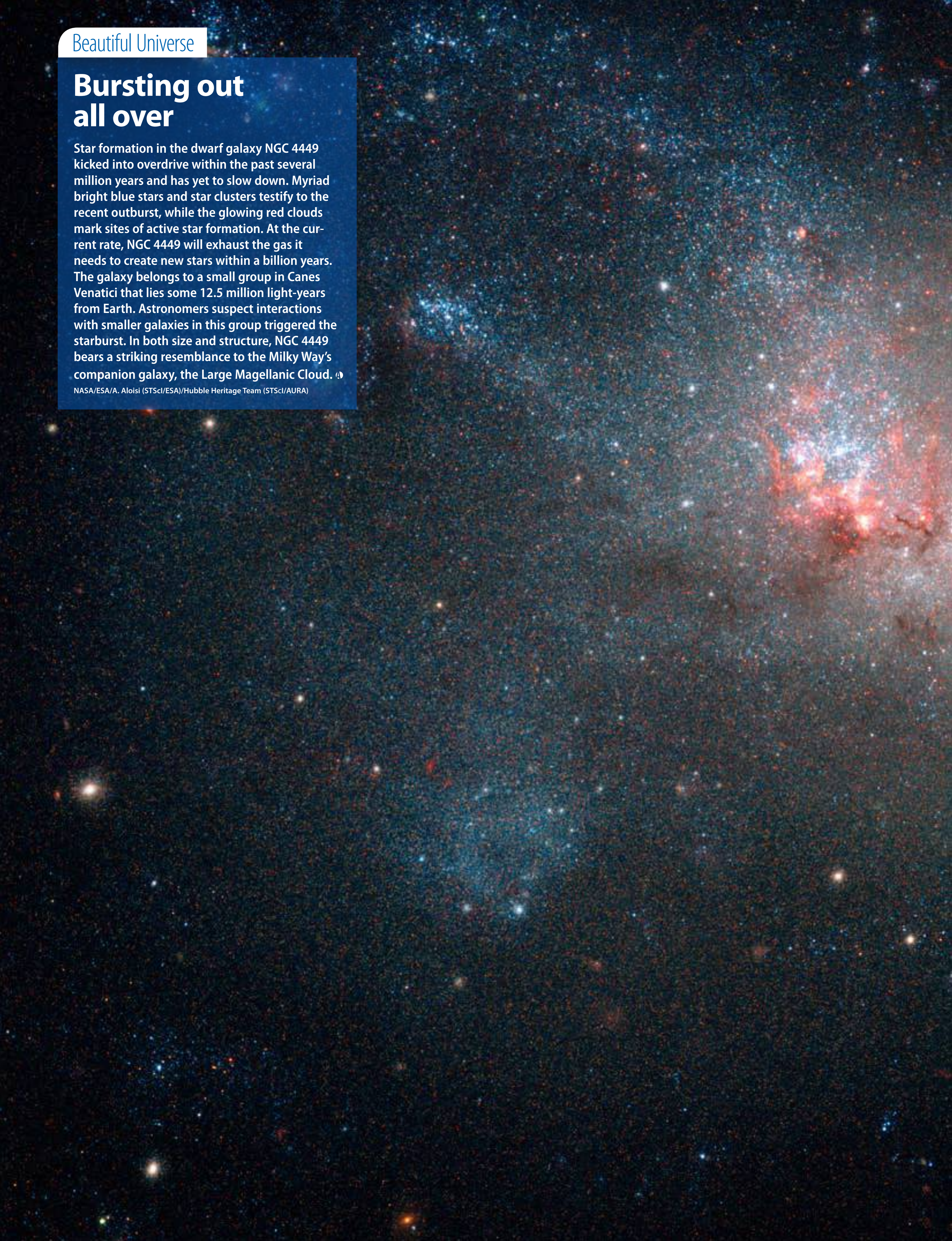
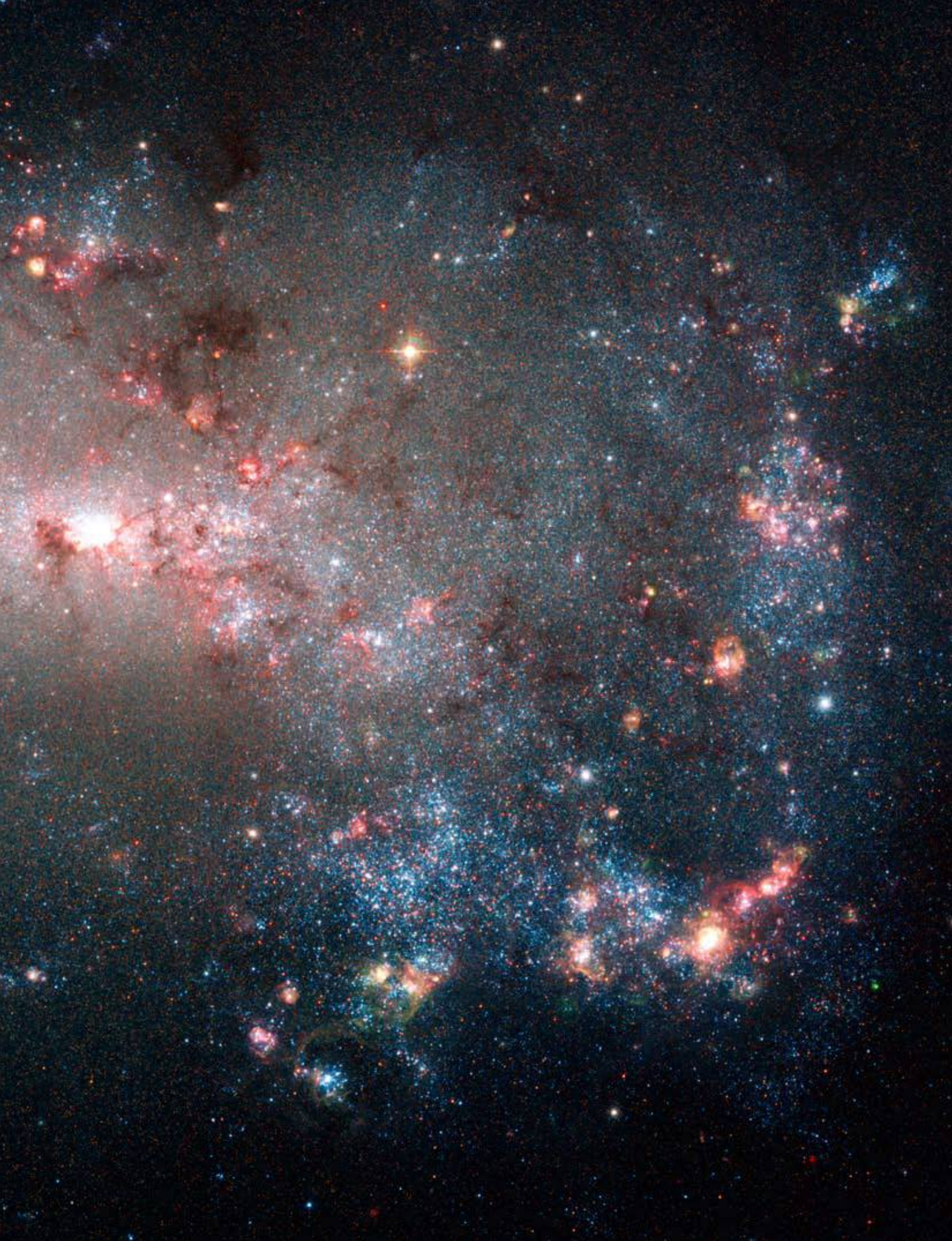


Bursting out all over

Star formation in the dwarf galaxy NGC 4449 kicked into overdrive within the past several million years and has yet to slow down. Myriad bright blue stars and star clusters testify to the recent outburst, while the glowing red clouds mark sites of active star formation. At the current rate, NGC 4449 will exhaust the gas it needs to create new stars within a billion years. The galaxy belongs to a small group in Canes Venatici that lies some 12.5 million light-years from Earth. Astronomers suspect interactions with smaller galaxies in this group triggered the starburst. In both size and structure, NGC 4449 bears a striking resemblance to the Milky Way's companion galaxy, the Large Magellanic Cloud.

NASA/ESA/A. Aloisi (STScI/ESA)/Hubble Heritage Team (STScI/AURA)



Astroconfidential

Go beyond the latest discovery, research, or theory and meet the professionals who make it all possible.

by Karri Ferron

OUR TURN

Avi Loeb

Professor at Harvard University and director of the Institute for Theory and Computation of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts

Harold Dorwin

What has been your favorite research area?

The first stars and galaxies. We know the universe was denser and hotter than the Milky Way or the Sun at early times, so these familiar objects couldn't have existed forever.

We are privileged to live in a time when we can explore critically the story of genesis (how the universe started and developed) with direct observations. Because of the finite time it takes light to travel to us from distant sources, we can see images of the universe when it was younger by looking deep into space through powerful telescopes.

I started to work on the first galaxies 2 decades ago when only a few theorists were interested in the field. It is gratifying to see an explosive evolution of this frontier now, with the potential of a wealth of new instruments under construction.

I just finished writing a popular book, *How Did the First Stars and Galaxies Form?* (Princeton University Press), that describes the latest developments in this field, which should come out in spring 2010.

What are some cool things you've done in your career?

In 1992, I was a postdoctoral fellow at Princeton. My neighbor, Andy Gould, was working on the phenomenon of gravitational microlensing by stars. One day I asked him, "Have you considered the effect of planets on the microlensing light curve?" Andy said, "No, but I suspect the effect would be small." An hour later, he rushed back to my office and said: "The effect is surprisingly large! Let's write a paper on the subject."

Today, microlensing is one of the major techniques used for discovering new planets and the only one that works at large distances across the galaxy.

Then, one morning in 2001, while taking a shower, I started wondering what the accelerated expansion of the universe might mean for future observers. Within a day, I submitted a short paper about it to *Physical Review* entitled "Long-Term Future of Extragalactic Astronomy."

My paper showed that as soon as the universe ages by a factor of 10, all the distant galaxies we now see will have exited from our horizon. The only galaxy visible to us will be the merger product of the Milky Way and Andromeda. This paper received a lot of attention in the media.

What do you like to do in your spare time?

I enjoy spending time with my two girls and wife and fixing things at home. I also enjoy watching the sky at night from our porch. It gives me the sense that we humans are too often preoccupied with ourselves. There is much more to the universe than meets the eye around us on Earth.

Astroideas *Where is the study of galaxy evolution going?*

Quite a few puzzles confront astronomers studying galaxy evolution. Among them is why some galaxies have gassy, dusty disks that form stars while other galaxies lack disks and have not formed stars in billions of years. Could one type of galaxy evolve into the other?

Important clues come from galaxies whose spectra indicate recent, but not current, star formation. Their stars' positions and motions suggest these galaxies had disks that were disrupted in mergers with other galaxies. We are working to learn whether such mergers are the dominant mechanism by which many galaxies are similarly transformed. If mergers are important, then a lot of galaxy evolution must take place where mergers are most common, in gravitationally bound groups of galaxies somewhat more dense than our own Local Group.

Another way galaxies could evolve, especially in the early universe, is by accreting gas from their surroundings. This inflowing gas allows galaxies to form stars.

Unfortunately, it is difficult to measure inflowing or outflowing gas in a distant galaxy, at least using its brightest spectral line, because the path light takes at that wavelength in escaping the gas is ambiguous. My colleagues and I are using some of the world's biggest telescopes to detect other spectral lines that are cleaner tests of gas inflows and outflows. We hope to obtain new insight into the role of gas accretion in the development of galaxies.

Ann Zabludoff

Associate professor of astronomy at the University of Arizona in Tucson

Dennis Zaritsky; Abell 3266: Michael Hudson and Russell Smith (University of Waterloo) and Gemini Observatory

A DAY IN THE LIFE OF …

Rachael and Barry Madore

Wendy **Freedman**

Director of the Carnegie Observatories in Pasadena, California

5:30 A.M. Catch up on previous day's e-mail because even though most of the West Coast is asleep, much of the world is up.

6:30 A.M. Time for some science. Write section of a paper, write a super-mongo script to plot some data, or read an article. Currently leading a new Carnegie Hubble Project using the Spitzer mid-infrared satellite to measure the Hubble constant to 3 percent accuracy.

9:30 A.M. Planning time with administrative assistant and meet with members of the administrative staff. Discuss planning for upcoming staff meetings, board meetings, travel, budget, fund-raising events, administrative issues, or teleconferences.

10:30 A.M. Meet with scientific staff to discuss funding for instruments, travel to conferences, postdoctoral selection, staff searches, grant proposals, and upcoming teleconferences with scientific collaborators.

11 A.M. If meetings don't run over, duck in briefly for morning tea and a discussion of astrophysics articles, results presented at recent scientific conferences, or the scientific colloquia.

12 P.M. Check in again with e-mail and eat some lunch.

1 P.M. Meet with Giant Magellan Telescope (GMT) project members, read reports on GMT, conduct teleconference with GMT partners, and participate in administrative and scientific staff meetings. GMT is scheduled for completion around 2019.

3 P.M. Meet with scientific collaborators to discuss progress; meet with Carnegie Observatories visitors.

4 P.M. Scientific colloquium. Topics range from distant galaxies to extrasolar planets, black holes, supernovae, dark matter, and dark energy.

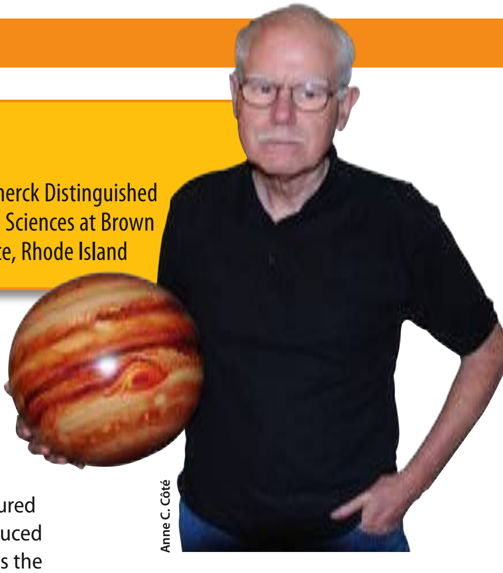
5 P.M. Deal with e-mail that takes longer than a few minutes.

8 P.M. Read and comment on some scientific papers, proposals, and other reports. Set agendas for upcoming meetings or write nomination and job reference letters.

GETTING TO KNOW

Jim **Head**

Louis and Elizabeth Scherck Distinguished Professor of Geological Sciences at Brown University in Providence, Rhode Island


Anne C. Côté

Basis for interest in planetary geology: While I was a graduate student studying limestone stratigraphy (rock layers) in the Appalachian Mountains in the mid-1960s, Brown University professor Tim Mutch announced to our graduate stratigraphy seminar: "There are no real problems left in Earth stratigraphy; let's apply the basic principles to the geology of the Moon and Mars." We thought he was crazy. Yet when I graduated a year later, my first job involved landing-site selection, traverse planning, and astronaut training for NASA's Apollo program.

Coolest thing about your involvement with the Apollo program: I learned that humans can achieve even the most difficult goals if they have inspirational leadership and maximize cooperation, rigor, and focus while minimizing competitiveness, pettiness, and negativity. A pervasive NASA can-do attitude, which is sadly missing in a lot of today's "can't-do" society, enabled the development of science and engineering synergism. This positive attitude ensured Apollo's success and produced the scientific legacy that is the basis for modern planetary geosciences.

Goals for your field: Encouraging interdisciplinary research is a big goal for me. The good news is that planetary geoscientists are getting terabytes of data successfully from different instruments in orbit around planets and becoming ever more specialized. But this trend is also resulting in a division of problems into ever-tinier pieces, which isn't good. I wish to encourage cooperation between Earth and planetary scientists — after all, Earth is a planet — as well as between different areas of study in planetary sciences (geologists, geophysicists, atmospheric scientists, etc.) to attack a series of problems in planetary evolution.

Astro**fascinations**

What fascinates you most about high-energy astrophysics?

High-energy astrophysics revolves around the study of celestial phenomena that emit largely in X-rays and gamma rays. My interest in this area stems from the fact that high-energy radiation is produced in the vicinity of the most exotic celestial objects in the universe — white dwarfs, neutron stars, and black holes. These are the remnants of stars' cores, after their deaths when they run out of fuel. The type of remnant left behind depends on the star's mass.

Neutron stars epitomize much of the research carried out in high-energy astrophysics. They emit X-rays from their hot surfaces, as well as from accelerated particles trapped in their powerful magnetic fields.

The interior of this type of stellar remnant is made up almost entirely of neutrons. The interior's mass is about 1.4 to 2 solar masses condensed into a volume with a radius of about 6 to 7.5 miles (10 to 12 kilometers). The resulting density is so high that one teaspoonful of a neutron star's matter would weigh a billion tons on Earth!

Due to the intense gravitational field, light emitted by the surface of a neutron star gets substantially deflected, as predicted by Einstein's general theory of relativity. This phenomenon, called gravitational lensing, is also a fascinating component of my research.

Rosalba **Perna**

Assistant professor of astrophysics at the University of Colorado at Boulder

courtesy Rosalba Perna

To learn more about the people featured this month, visit www.Astronomy.com/toc.

South American stargazing

We read *Astronomy* frequently, and it was one of the inspirations for us to begin building the Astronomical Observatory of Zaquencipa here in Colombia. It's sometimes difficult to find your magazine in our country, but it helped and motivated us to learn about others who love astronomy.

Since we enjoy this science so much, it has been our long dream to work toward the construction of an astronomical observatory. The site is in the valley of Santo Ecce Homo. In addition to this, we are working on building the "Kosmos Space Museum," a facility that displays the adventures behind the conquest of space. Our work is directed primarily to help low-income children who do not have the opportunity to observe the sky through a telescope.

Our observatory has been under construction for 2 years because in our country it's difficult to find funding for research in this field. The structure, 36 feet long by 15 feet wide (11 meters by 4.5 meters), will be divided into three sections: the upper part, with a roof mounted in bearings and steel rails, will house the telescope; the middle area is the office where we will keep the computers; and the lower part will be for the laboratory. The main telescope (telescope Elkeve) is a 17.5-inch f/4.5 reflector.

OBSERVATORIO
ASTRONOMICO

The Astronomical Observatory of Zaquencipa in Colombia, under construction for 2 years, will give local children the chance to observe with a telescope. Hernan Charry

— **Hernan Charry and Linna Gonzalez,** Santo Ecce Homo, Boyacá, Colombia

Kovac Planetarium appreciated

During the summer when the wife and I visited Lake Tomahawk in Wisconsin, we found a brochure for Kovac Planetarium and stopped by for a visit. What a nice surprise! We're glad we went; I've never seen a planetarium like it before.

The most amazing thing was how real the sky was inside the dome. Kovac may not have all the flash and displays of the larger planetariums, but it more than makes up for that with the incredible realism of its nighttime sky. We couldn't see any lights shining through holes in the ceiling, just the glowing stars in their true positions.

Neither I nor anyone in my local astronomy club had ever heard of this place, so I'm doing whatever I can to get the word out. — **Larry Smith,** Ingleside, Illinois

Life is a battery

Your September story, "The day the earth came to life," asked what problem the emergence of life solved. The short answer must be "thermal equilibrium."

A better version of the question would be, "What problem did the emergence of life attempt to solve?" In a nutshell, Earth receives more solar energy than it can absorb or reflect due to the atmosphere's trapping effect. That energy has to go somewhere, and some of it goes into storage. The purpose of life must then be to keep this energy and store it for future use.

Just look at that spare tire around your gut, or the heat released by the wood in a campfire, or the honey in a beehive. The purpose of the first life form was to convert and store energy. The seed of life is simply the smallest battery known to man. — **Michael C. Redman,** Vancouver, Washington

Farewell, IYA 2009

As we all know, 2009 was the International Year of Astronomy (IYA), and now, already, it's over. A little thanks may be in order.

First, I would like to recognize all the astronomers, both amateur and professional, who took the time to set up their equipment on sidewalks and parks, allowing the general public to see how wonderful our universe truly is. But because IYA also marked the anniversaries of some important events in space history, let's not forget those who came before us. It was 400 years ago that Galileo turned his first telescope to the stars, and 40 years since the Apollo Moon landing.

As the IYA becomes only a memory, we can instead look forward to the future. New and better telescopes, computers, and other tools await astronomers, both amateur and professional. The future will no doubt bring new discoveries and events that will be recorded in history. It's nice to think that someday all of our work, discoveries, and inventions will be celebrated and recognized by generations yet to come, as we have celebrated the past 400 years.

— **Gordon R. Lyell**, Johnston City, Illinois

Correction

On page 53 of the October issue, Epsilon Aurigae's eclipse is incorrectly stated as reoccurring in 2046. It actually reoccurs in 2036. — ***Astronomy* Editors**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Web**talk**

Tune in to our weekly observing podcast

Each week, *Astronomy* magazine Senior Editor Michael E. Bakich, a master at explaining how to observe, records a podcast about three objects or events in the sky: one you can see without optical aid, one with a small telescope, and one with an 8-inch or larger telescope. Michael also shares historical information about the objects. We post the podcast every Thursday, so it's ready for you to download and take with you on your weekend observing runs. The podcast is available to registered members of Astronomy.com. Registration is free, so sign up today!

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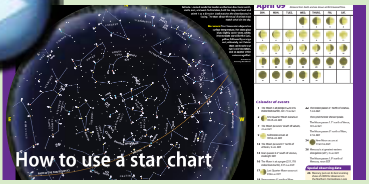

How to use a star chart

Featured video

Senior Editor Richard Talcott helps you navigate the night sky using *Astronomy* magazine's pullout star chart — located in the center of each issue.

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— Phil Harrington,
Astronomy Magazine, August 2009

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Strange Universe

by Bob Berman

2010: a real space odyssey

Who needs imaginary science with all the exciting events taking place this year?

Reader mail often includes worried questions about make-believe astronomy. Lately, "Planet X" has been big. This is an imaginary world that supposedly will soon crash into us, and the government has forced astronomers to keep it secret. This silliness comes mostly from fake-science paranoid web sites. If some of your friends are fearful that a horrible comet or planet is about to destroy Earth, just tell them this:

Most astronomers do not work for the government, but for universities or private institutions. They submit their discoveries to journals and periodicals over which the government has absolutely no control. Dramatic new information leaks out quickly, flashing around the world via the Internet. There's no way the government could suppress it — or has ever tried. Planet X does not exist. As for astronomers keeping an imminent collision hush-hush, well, we wouldn't know how. We're blabbermouths by nature.

So let's blabber about real stuff — the fabulous events coming up in 2010. Written MMX, this is the shortest Roman numeral year until 2050. Yet it's long in sky treasures. Here are my favorites:

Mars makes its closest approach of the year January 27. It'll be nice and high. But at some 60 million miles (96 million kilometers), it's a distant opposition. Still, the Red Planet will manage to nearly match Sirius in brilliance, creating a wonderful orange-and-blue contrast in the winter sky. Two nights later we get the year's nearest Moon, hovering next to Mars. And it's a Full Moon to boot! Watch this biggest Moon of 2010 rise at sunset on the 29th.

Skip to March, which belongs to Saturn. With its rings strikingly near edgewise, it reaches its brightest, closest point to us on the 21st. This will be its final strange opposition (at only magnitude 0.5) until the mid-2020s. After this year, the shiny rings are wider open.

Browse the "Strange Universe" archive at www.Astronomy.com/Berman.

Then our thoughts turn to tiny Mercury, which some people imagine is hard to observe. To grasp how false this is, look for it the first 10 days of April. The innermost planet is joined all the while by brilliant Venus to its left. Go out 40 minutes after sunset. You'll catch that charbroiled orange planet, guaranteed, or double your money back. Send all invoices to our editor, Dave Eicher.

The first 10 nights of June bring a close meeting of orange Mars and Leo's blue star Regulus. Their brightnesses match; the fun lies in telling them apart by color alone.

The real sky offers all the excitement anyone could want.

In August, for only the fourth time this century, we get perfect moonless conditions for the famous Perseid meteor shower on the 11th. If you're an urbanite, this is the time to visit your friends in the country. Bring them some city take-out food and call it even.

Jupiter owns September. The giant world reaches opposition on the 21st, shining at its biggest and brightest since 1963. At an unusually brilliant magnitude –2.9, Jove dominates the sky. Blue-green Uranus comes to opposition on the 21st, too, so it floats nearby, directly above Jupiter through binoculars. A twofer. That night, the moon Europa crosses Jupiter's disk in a cool transit. Check it out at 11 P.M. EDT.

Jump ahead to early December, when Venus reaches its greatest brilliancy of 2010 an hour before dawn at a shadow-casting magnitude –4.9. Then on the 13th the Geminids will perform splendidly. These are the year's most abundant meteors, with the Moon setting soon after midnight to nicely darken the skies. Made of odd material that resembles no other meteor shower, Geminids come at us sideways and cross the sky relatively slowly.

All meteoroids migrate closer to the Sun over time. Summer's beloved Perseids are now slowly finishing up their interceptions of Earth's orbit, which is sad indeed. In contrast, the Geminids are the future of meteor-watching. Because they're more fully streaming inward into us, they're getting better and better each December.

The year saves its best for last. It's the century's first total lunar eclipse that's visible start-to-finish from all of the United States and Canada. Watch for it slam bang on the opening hours of the solstice, December 21, beginning at 1:32 A.M. EST. And listen up: That eclipsed Moon also happens to be the highest-up Full Moon until the 2020s! It'll reach that lofty perch at local midnight, just before the eclipse starts.

See, we don't need fake science. The real sky offers all the excitement anyone could want. But what's with the numerology? Jupiter, Saturn, and Uranus all at opposition on the 21st? Plus the highest Full Moon of the decade? And a total eclipse? Joining the solstice? All on the 21st? Is the universe suddenly into "21" — blackjack? Maybe a great meteor will appear if I look at the sky and say, "Hit me!"

I'll just hope Planet X isn't listening.

Contact me about my strange universe by visiting **skymanbob.com**.

ASTRONOMICAL CALENDAR 2010

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—*Astronomy* magazine

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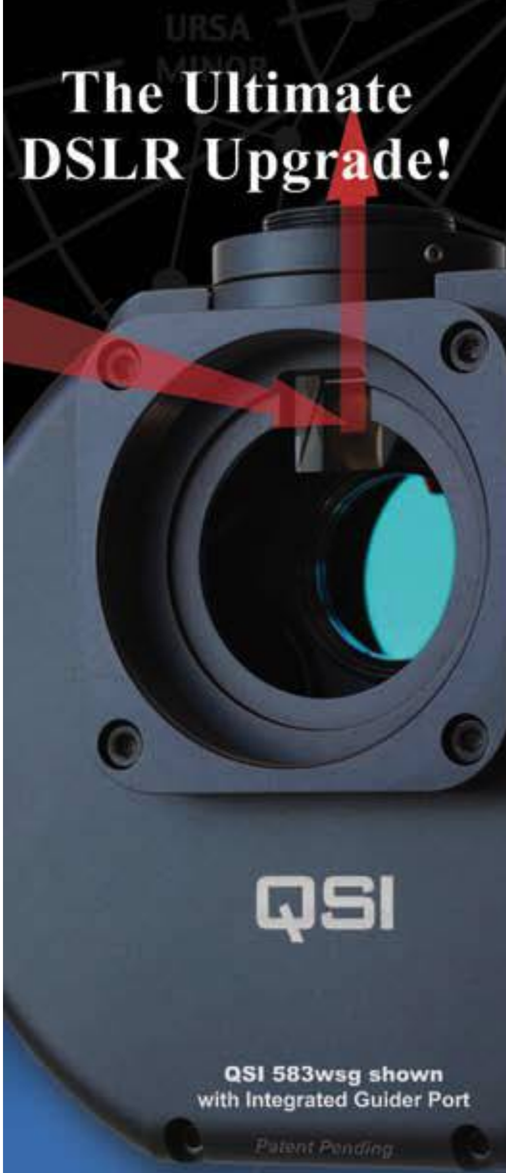
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Evening Stars

by David H. Levy

Living and breathing astronomy

Friends, events, and places led me to spend my life among the stars.

Each of us has different reasons for being attracted to the night sky, whether because of family or friends or just by looking up on our own. This month I shall introduce you to some of my reasons.

I begin with Leo Enright, who was the subject of my column only 3 months ago. I mentioned then that he had an aortic aneurysm 2 months after watching the 1999 solar eclipse. On August 11, 2009, during the maximum of the Perseid meteor shower and on the 10th anniversary of that wonderful 1999 eclipse, Leo died in his sleep. His influence and wisdom had an incalculable effect on his many friends and colleagues, including me. More than anything else, he explained to me after my divorce from my first wife that I could still live productively while single — advice that carried me right through my first 21 comet discoveries and 25 books and that led to my new marriage with Wendee.

It is hard to overstress the importance that a mentor can have. I have written biographies on some of them, like Bart Bok, Clyde Tombaugh, and Gene Shoemaker. Mentors can be people, and even ideas or places can influence your life. One such place was the Children's Asthma Research Institute and Hospital, which from 1907 to 1981 stood proudly in west Denver. What, you might ask, does a medical facility have to do with astronomy? For me, everything.

I lived there for 14 months, from September 1962 to November 1963, and while there I took advantage of the Colorado sky to pursue astronomy. The asthma home was divided into several dormitory buildings called cottages. To the north of Albert cottage and to the east of the research building stood a large open field, unhindered by lights. It was at this place that I set up my telescope for each of the observing sessions I had while there.

Browse the "Evening Stars" archive at www.Astronomy.com/Levy.

FOR A CHILDS SAKE

Although the asthma home no longer exists, it was once a lively medical center and observing site. Under the entrance, which reads "For a child's sake," stand the author and his father, Nathaniel Levy, in April 1963. Dr. Edith P. Levy

Although I never observed an eclipse, I actually did view the Moon during the penumbral eclipse of January 9, 1963. Because I didn't know an eclipse was in progress at the time, I failed to note any change in the Full Moon's illumination that hour; however, I did spot a crater — probably Tycho or Copernicus — that I had not seen before.

One story I'll never forget involves trying to sight Neptune. I'd often venture outdoors into the damp air, find clouds, and postpone my attempt to find the eighth planet. By the end of each observing session, I'd be wheezing, so I'd need to head to the hospital for medication.

After one of these visits, my physician, Hyman Chai, examined me, pronounced the attack over, and asked why I was having so much asthma lately. "I've been outdoors a lot trying to find Neptune," I explained. "Until the weather improves," I suggested meekly, "I guess I'll stop searching for Neptune."

"No, you won't," Chai responded firmly. "Your orders are to keep on going out until you succeed in locating Neptune. If you get asthma, come by for a nebulizer. But I won't let a patient of mine stop doing what is important to him just because of an asthma attack."

I never forgot his words, and late in the evening of June 3, 1963, I finally located that distant world as a faint bluish "star," just where it was supposed to be.

The asthma home also had another unexpected benefit. Because kids can be cruel, and I was an unathletic wimp, I became a frequent object of pranks and jokes. Sometimes the other children would add unwanted characters and words to my youthfully careless charts and records of observations. None of these tricks ever did any real harm, but they did encourage me to "clean up my act" and take more careful, though still handwritten, records.

That year I spent in Denver was precious. I enjoyed watching the evening sky panorama on its many clear nights, drawing maps of the Milky Way, charting the progress of mighty Jupiter's four Galilean moons every night for a month, and witnessing several meteor showers. Years later, another place-mentor, a campsite in the Adirondacks, nurtured the seed that the medical facility had planted, leading to my specializing in comet searches in late 1965.

Each time I enter or leave our home, I walk past the little 3½-inch reflector that accompanied me to Denver. The telescope still works, but what it holds best are the memories of that critical year I spent at the asthma home.

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Mars plan Mars scientists the world over gathered at Arizona State University September 9 to 11 to determine what the next goals and priorities should be for exploring the Red Planet.

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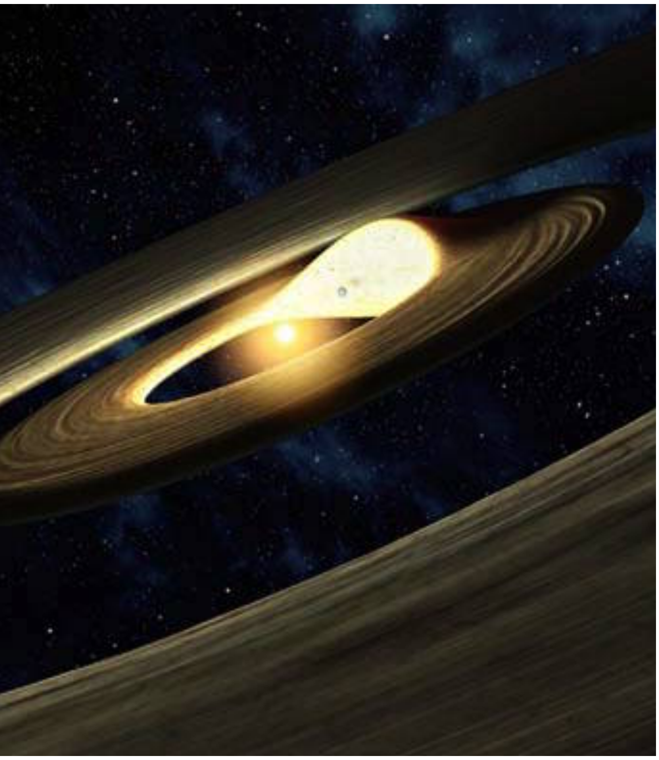


Large-scale duster. NASA's Spitzer Space Telescope observed a likely planet-forming disk with a companion (either a planet or another star) pushing material around the disk, as illustrated here. NASA/JPL-Caltech

Astronomers see swirling planetary material

For 5 months the Spitzer Space Telescope observed light from a swirling disk of gas and dust around the young star LRLL 31. However, the light from this likely planet-forming disk varied in unexpected ways. Astronomers, led by James Muzerolle of the Space Telescope Science Institute in Baltimore, may be witnessing planet formation in real time. The finding will appear in a future issue of *The Astrophysical Journal Letters*.

The astronomers studied young stars, about 2 to 3 million years old, in the IC 348 star-forming region. A few of the stars showed unexpected brightness variations, and the researchers performed follow-up observations with all three of Spitzer's instruments on one of those stars — LRLL 31. They saw that both the intensity of the light and the wavelength varied over timescales of just a few weeks.

A theory of planet formation says that as planetary disks evolve, dust particles slowly collect more mass, like sticky snow. As the objects get bigger, they carve gaps in the disks. If a companion to the star is orbiting in this gap, it could be pushing a clump of the material around the planet-forming disk. "A companion in the gap of an almost edge-on disk would periodically change the height of the inner disk rim as it circles around the star. ... This is exactly what we observe in our data," says Elise Furlan of NASA's Jet Propulsion Laboratory and co-author of the study.

The group plans to continue observations of LRLL 31 with ground-based telescopes to see if it can directly detect a companion. — **LIZ KRUESI**

22 Stellar remnant spins too slowly

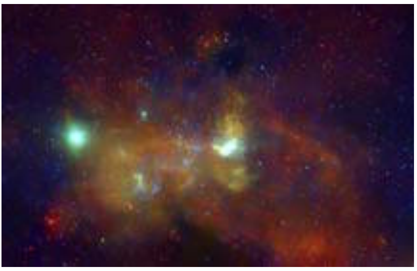
23 Mars may have had a wetter atmosphere in the recent past

24 Record-breaking lightning storm observed on Saturn

26 This super-Earth is rocky

27 Scientists discover stellar Rosetta stone

NASA releases new view of Milky Way center



NASA/CXC/UMass/D. Wang et al.

Galactic vista. The Chandra X-ray Observatory captured this new image depicting the center of the Milky Way Galaxy. Low-energy X-rays are colored red, middle-energy X-rays green, and high-energy X-rays blue to render the normally invisible light visible.

To launch the first day of the "Chandra's First Decade of Discovery" symposium September 22, NASA released a stunning new vista of the center of the Milky Way Galaxy. The Chandra X-ray Observatory took the picture, which highlights some of the chaos and turbulence found in the galactic center because of both bright young stars and black holes. All this surrounds a central supermassive black hole known as Sagittarius A* (pronounced "A-star").

Chandra is particularly suited for studying the galactic center because it uses X-rays, famous for their ability to penetrate matter, to see through all the gas and dust that block visible light. In the image, the scientists combined low-, middle-, and high-energy X-rays to show off the various phenomena at the center of the galaxy.
— **BILL ANDREWS**

NEXT MONTH
in the February issue

TONY HALLAS

Astronomy
The world's best-selling astronomy magazine

Top 10 stories of 2009
Cosmologists found more evidence of dark energy, astronauts returned Hubble to prime condition, astronomers photographed worlds beyond our solar system, and more.

How astronomers probe weather on exoplanets
Astronomers can approximate the weather on distant worlds.

Illustrated: Explore our neighborhood of galaxies
Some 50 galaxies crowd around the Milky Way in our Local Group.

10 tips for Moon watchers
Mountain ranges, vast volcanic plains, and more than 1,500 named craters make the Moon a delightful target.

How to start a meteorite collection
Learn Raymond Shubinski's two main tenets of meteorite collecting, and meet some of the dealers he trusts.

Dancing with the galaxies
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NASA/ESA/The Hubble Heritage Team (STScI/AURA)

Memorable finale. At the end of its life, a Sun-like star expands and ejects its outer gaseous layers. Radiation from the leftover core, a white dwarf, lights up the gas clouds to create a gorgeous planetary nebula.

Stellar remnant spins too slowly

A team of astronomers has borrowed a technique from geologists to probe the interior rotation of a white dwarf star (the stellar remnant of a Sun-like star). They found that white dwarf PG 1159-035's interior spins much slower than expected, which means astronomers don't fully understand how stars evolve. The study appeared in the September 24 issue of *Nature*.

Scientists expected a much faster rotation because as a Sun-like star begins to die, it puffs up as a red giant. It loses its outer layers of gas while the inner portion (the core) collapses into a white dwarf. In the same way an ice skater speeds up when she brings her arms close to her body, astronomers expected a white dwarf's rotation to speed up.

So, according to theory a white dwarf star should complete a rotation in a few seconds to a few minutes. However, for years astronomers have observed that the surfaces of white dwarfs appear to be rotating on scales of days or even longer. A group led by Stéphane Charpinet of the Laboratoire d'Astrophysique de Toulouse-Tarbes in France looked at pulsations from PG 1159-035 to determine if the slower rotation rate went deeper than the star's surface.

The group found that the star's inner structure also rotates slowly — it completes one rotation in about 33.6 hours. So it must have lost some of its momentum at another point in its stellar lifetime. The team is applying its technique to similar stars to determine whether this finding applies to other white dwarfs. — **L. K.**

The third time is not charmed

NASA's MESSENGER spacecraft skimmed within 142 miles (228 kilometers) of Mercury's surface at 5:55 P.M. EDT September 29. MESSENGER had flown past Mercury twice before. But this flyby allowed the spacecraft to see a thin strip of the inner planet no one had ever seen up close before.

The probe took hundreds of images on the inbound leg of its journey. With the new photos, scientists have now seen almost all of Mercury's surface between 60° north and 60° south latitude. (Much of the polar regions remain terra incognita.)

The observations revealed plenty of impact craters, smooth plains, and at least one double impact basin. In addition to the newly discovered features, which do not yet have names, MESSENGER viewed significantly more terrain under different lighting conditions. It likely will take months for scientists to sort out all the new data.

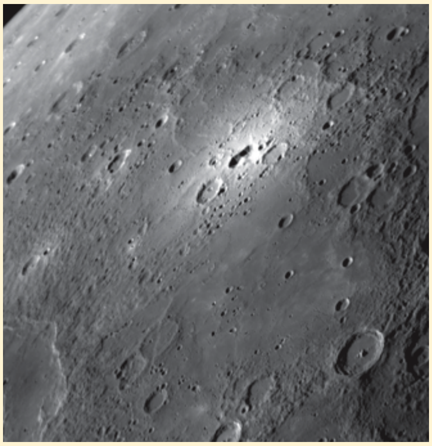
Unfortunately, the outbound leg of MESSENGER's journey did not go as well. Four minutes prior to closest approach, the spacecraft went into "safe mode" and stopped executing its planned observations. A spacecraft enters safe mode whenever its onboard computer senses something has gone awry, which protects the vehicle and saves all data.

The trouble arose while MESSENGER was in Mercury's shadow and operating on battery power. "We believe this transition was initiated by the onboard fault management system due to an unexpected configuration of the power system during eclipse," says MESSENGER Mission Systems Engineer Eric Finnegan of Johns Hopkins University's Applied Physics Laboratory in Laurel, Maryland.

Mission operators turned MESSENGER back on at 12:30 A.M. September 30, and all systems seemed in excellent shape. The spacecraft returned all its stored data to Earth later that day.

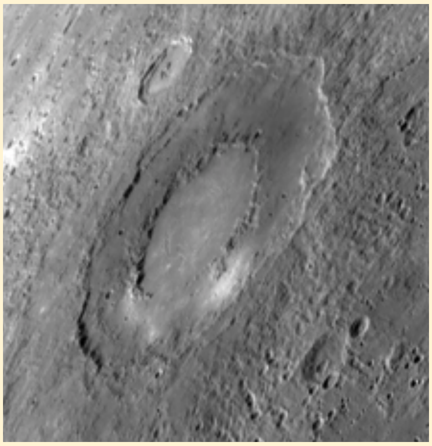
Despite the hiccup, the flyby accomplished its primary purpose — setting MESSENGER on course to return to Mercury March 18, 2011. The spacecraft then will fire its rocket and begin orbiting the planet. The probe will follow a highly elliptical path that will bring it closest to the planet's north pole. This primary mission should last 1 Earth year, during which scientists will get a detailed look at Mercury's global environment.

— **RICHARD TALCOTT**



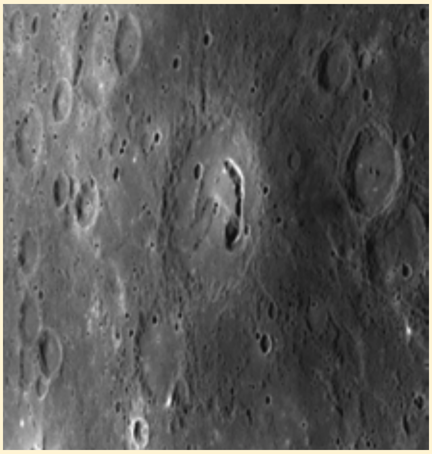
NASA/JHUAPL/CIW

Bright spot. An irregular depression lies at the center of this bright region, seen under excellent lighting conditions during MESSENGER's third flyby. Scientists think volcanism may have created the depression.



NASA/JHUAPL/CIW

Seeing double. MESSENGER discovered this double-ring impact basin in terrain it saw for the first time. The basin's outer rim spans some 160 miles (260 km).



NASA/JHUAPL/CIW

The pits. Scientists call the arc-shaped depression at the center of this newly imaged region a "pit crater." Such craters have no rims and often have steep sides and an irregular shape.

Comet & Co. light up Astronomers announced September 16 at the European Planetary Science Congress that multiple "mini-comets" helped make 2007's Comet 17P/Holmes more than a million times brighter in less than a day.

Mars may have had a wetter atmosphere in the recent past

Mars may not always have been as dry and arid a wasteland as it is now, according to a paper in the September 25 issue of *Science*. Using NASA's Mars Reconnaissance Orbiter to study the sites of recent meteorite craters, astronomers discovered frozen water hidden just below the surface of the Red Planet. The discovery came as a surprise because the water occurred at a much lower latitude — approximately halfway between the north pole and the equator — than scientists had ever expected it could exist.

"This ice is a relic of a more humid climate from perhaps just several thousand years ago," says Shane Byrne of the University of Arizona, a member of the team that captured and analyzed the unprecedented images. He and his co-authors noticed that the recently exposed ice didn't last long, vaporizing into the atmosphere in just a few months. This implies higher levels of long-term atmospheric water vapor than astronomers previously suspected Mars capable of.

"The other surprising discovery is that ice exposed at the bottom of these meteorite impact craters is so pure," Byrne says. "We were able to figure out, given how long it took that ice to fade from view [and into the atmosphere], that the mixture is about 1 percent dirt and 99 percent ice."

Scientists hope to continue taking advantage of the small but frequent impact craters dotting the planet's surface to learn more about the martian atmosphere and climate. — **B. A.**

J. Bell (Cornell U.)/P. James (U. Toledo)/M. Wolff (SSI)/A. Lubenow (STScI)/J. Neubert (MIT/Cornell)

Martian water. Recent findings of water ice just below the surface of Mars, shown here in a 2001 Hubble Space Telescope photo, suggest that the Red Planet may have recently had a much wetter atmosphere than astronomers ever expected.

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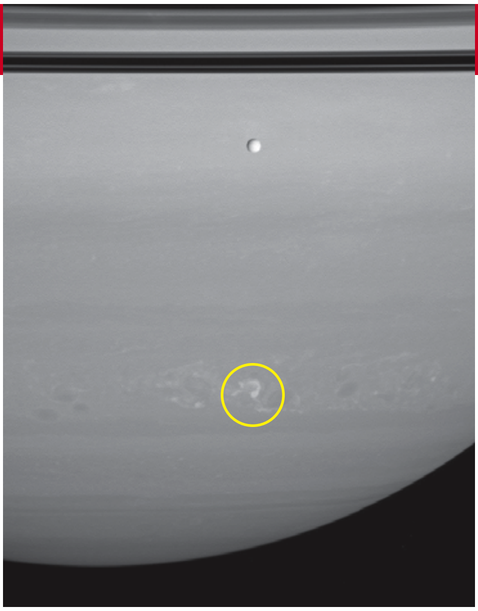
Astro**news**

Record-breaking lightning storm observed on Saturn

A lightning storm on Saturn broke the record for the solar system's longest continuously observed thunderstorm, astronomers announced at the European Planetary Science Congress September 15. The storm has raged since mid-January 2009. The previous record-holder, a storm 7.5 months long, also occurred on Saturn. The ringed planet is famous for hosting such storms: It's home to a region 35° south of the equator so turbulent that scientists nicknamed it Storm Alley.

"These lightning storms are not only astonishing for their power and longevity, the radio waves that they emit are also useful for studying Saturn's ionosphere," says Georg Fischer of the Austrian Academy of Sciences, who presented the discovery. These radio waves, about 10,000 times stronger than their Earth counterparts, were detected using instruments on NASA's Cassini spacecraft, in orbit around Saturn since July 2004. Cassini's results have confirmed Voyager's earlier observations showing Saturn's day side with approximately 100 times more ionization activity — likely the result of lightning — than its night side.


NASA/JPL/Space Science Institute

Storm Alley. A train of storms rages through Saturn's southern hemisphere in this picture, as the moon Tethys and the rings circle the planet above.

The record-breaking thunderstorm is the ninth Cassini has observed, and most have occurred in Storm Alley. "The reason why we see lightning in this peculiar location is not completely clear," Fischer says. "It could be that this latitude is one of the few places in Saturn's atmosphere that allow large-scale vertical convection of water clouds, which is necessary for thunderstorms to develop. However, it may be a seasonal effect." — **B. A.**

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25 years ago in *Astronomy*

January 1985

In the January 1985 issue of *Astronomy*, then-Assistant Editor Francis Reddy examined how astronomers could use computers to simulate distant or complex events in "The universe, bit by bit."

Although the pictures (and even the font) seem technologically primitive today, at the time they were absolutely state of the art and represented an exciting new direction for space researchers to explore. Whether visualizing the inner workings of binary stars, supernovae, or even black holes, the simulations allowed astronomers their first glimpses into phenomena no one had ever seen before.

As Reddy wrote, "In astronomy, as in these other fields, computer simulation holds great promise." Twenty-five years later, it still does.

10 years ago in *Astronomy*

January 2000

In the January 2000 issue of *Astronomy*, Tom Siegfried wrote about the inevitable "Exodus from Earth," detailing humanity's need to find extraterrestrial shelter once the Sun makes our planet uninhabitable.

Drawing from current science as well as *Star Trek*, *Contact,* and the *Foundation* novels, Siegfried examined the problems of suspended animation, faster-than-light travel, potential destinations, and finding appropriately habitable planets. Our descendants may not technically be human, whether because of self-directed evolution or a fusion with technology, but they will need to address these issues.

"As a species we must continue to look to the stars," Siegfried wrote, "because someday — and sooner than we might have imagined — that's where we're going to have to go." — **B. A.**

QUICK TAKES

SIUE PODCAST WINS AWARD

The daily podcast "365 Days of Astronomy," produced at Southern Illinois University Edwardsville, won the Parsec Award for Best Infotainment Podcast.

RADIATION BELT ON SATURN

Using the Cassini spacecraft, scientists discovered a new, temporary radiation belt on Saturn, Elias Roussos of the Max Planck Institute announced at the European Planetary Science Congress September 14.

SIMULATING SUPERNOVAE

A team of researchers reported in the October 1 *The Astrophysical Journal* that it has created the first complete simulation of a white dwarf's final hours, when it explodes as a type Ia supernova.

PLANCK SEES FIRST LIGHT

The European Space Agency's Planck mission, designed to study the cosmic microwave background left behind by the Big Bang, began surveying the sky August 13.

GALACTIC GAMMA RAYS

Astronomers reported in the September 24 issue of *Science* that they had detected gamma rays from starburst galaxy NGC 253, implying dense supernova activity packed into the galactic center.

LOFAR'S WORK BEGINS

ASTRON's LOw Frequency ARray (LOFAR) detected the bright quasar 3C 196 August 20, providing "interferometric fringes" — equivalent to first light for an ordinary telescope.

KECK SPIES THE SKIES

Astronomers at W. M. Keck Observatory in Hawaii spotted an extended, double-layered dust disk orbiting 51 Ophiuchi, suggesting it may be a protoplanetary system. The team reported its finding in a paper in the October 1 *The Astrophysical Journal.*

HAUMEA'S DARK SPOT

Astronomers announced September 16 at the European Planetary Science Congress that they'd discovered a dark red spot likely rich in organic compounds on the distant dwarf planet Haumea.

L.I.F.E. IMAGING

An article in the September 24 *Astrobiology* explains how a laser technique that detects bacteria in frozen Antarctic lakes could uncover signs of life in the martian polar regions.

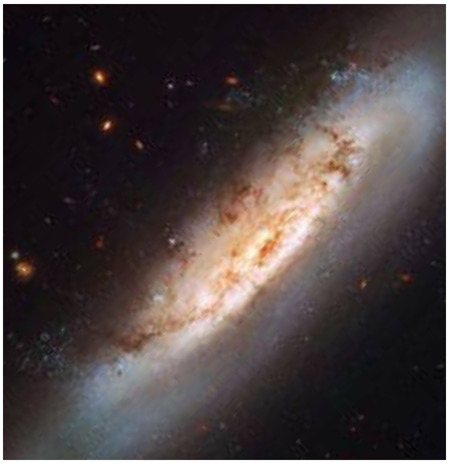
2009
Astronomy magazine
Out-of-this-world public program

Now accepting submissions for annual $2,500 award

Astronomy magazine will present its 2009 Out-of-this-world Award to a club or organization that has shown excellence in astronomy outreach activities. The $2,500 award focuses on ongoing programs by an educational or civic organization, and recognizes a group's sustained efforts to involve its local community in the science and hobby of astronomy. The prize money is to be used for future astronomy outreach activities. *Astronomy* editors will review each entry and select a winner.

The 2008 award went to the Cincinnati Observatory Center in Ohio, which distinguished itself by giving away forty 8-inch Dobsonian telescopes to local science teachers and high-school students in its "40 Telescopes" program.

The entry form for *Astronomy's* 2009 Out-of-this-world Award is available for download online at www.Astronomy.com/award. Applications and material must be postmarked by January 15, 2010. The winner will be announced by March 1.


NASA & ESA

High-speed chase. Hubble captured gas and star-forming regions being stripped from NGC 4522 as it speeds through its galaxy cluster. This spiral galaxy is some 60 million light-years away.

Hubble views distorted galaxies

Before last May's servicing mission, the Hubble Space Telescope captured images of two spiral galaxies being stripped of some material as they move through their neighborhood. Astronomers released the images September 30.

Both galaxies lie in the Virgo cluster, some 60 million light-years distant. Such a galaxy cluster contains gas between galaxies, which is called the "intracluster medium." As the galaxies NGC 4522 and NGC 4402 speed through the cluster, the collision between the gas and the galaxies strips material from the galaxies. This process is called "ram pressure stripping."

NGC 4522 travels at about 6 million mph (10 million km/h). This motion through the intracluster medium has pulled star-forming regions out of the galaxy, which are visible as bright blue patches above and on both sides of the galaxy. By studying galaxies that exhibit ram pressure stripping, astronomers can better understand galaxy evolution. — **L. K.**

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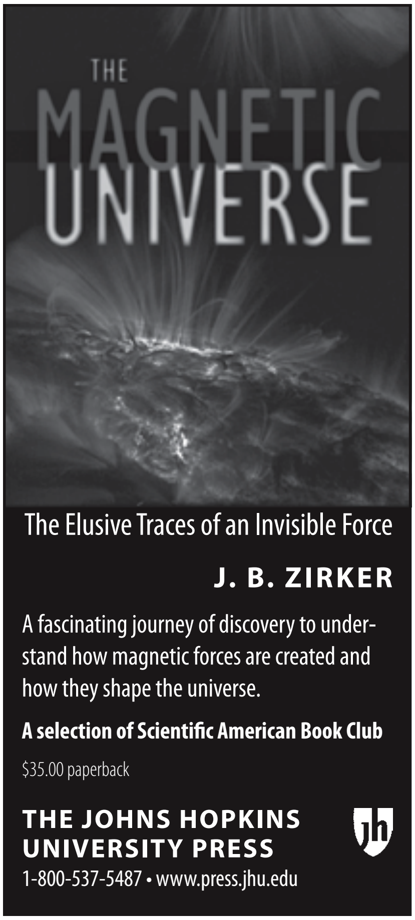
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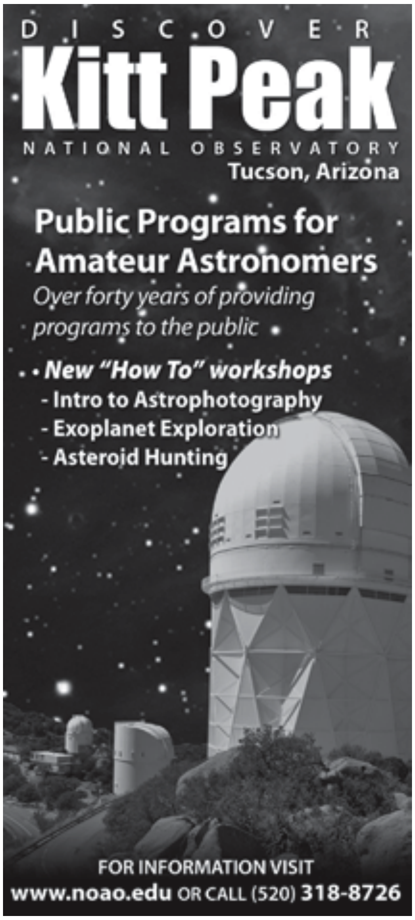
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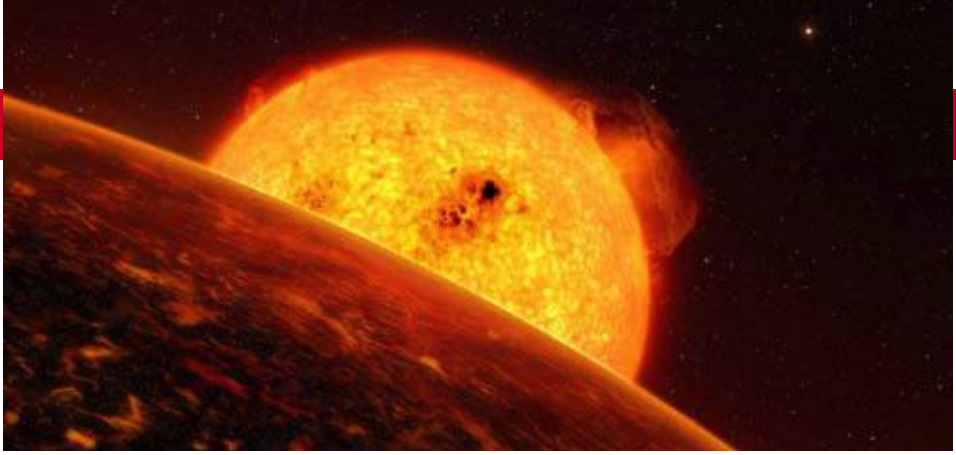
This super-Earth is rocky

Astronomers have verified that extrasolar planet CoRoT-7b has a hard surface and a density similar to Earth's. This makes it the first confirmed rocky exoplanet. The team, led by Didier Queloz of Geneva Observatory in Switzerland, published its study in the October 22 issue of *Astronomy & Astrophysics*.

In February 2009, astronomers with the Convection Rotation and Planetary Transits (CoRoT) satellite announced they had discovered a planet with just twice Earth's diameter. CoRoT observes stars for small periodic dimming, which implies a planet is transiting the star's face. From the transit method, they could determine CoRot-7b's diameter, but calculating the mass was more difficult.

Enter the European Southern Observatory's High Accuracy Radial velocity Planet Searcher (HARPS) spectrograph. A planet orbiting a star will gravitationally tug slightly on the star; spectrographs measure these tugs as velocity wobbles. Queloz and colleagues used HARPS to measure precise velocity variations in the star's movement. They were able to tell apart signals from the planet's tugs from wobbles on the star's surface to determine CoRoT-7b is 4.8 times Earth's mass. The mass, combined with its diameter of 1.7 Earth-widths, gives the exoplanet a density almost identical to Earth's.

This planet, however, isn't "earthlike." It orbits so close to its star — about 23 times closer than Mercury orbits the Sun — that its surface is likely molten rock. — **L. K.**



Lava planet. This illustration shows how unpleasant the weather is on confirmed rocky planet CoRoT-7b. It sits 23 times closer to its star than Mercury is to the Sun. ESO/L. Calcada

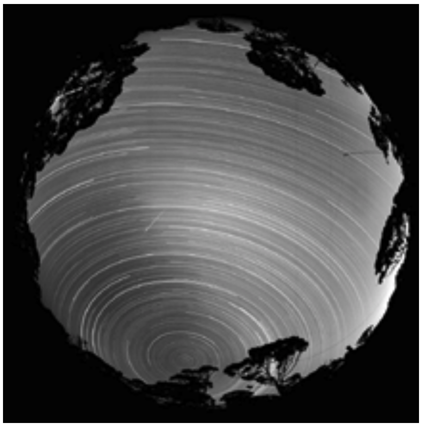


Image courtesy The Desert Fireball Network

Falling rock. The Desert Fireball Network exposes an image for most of the night so it can catch a fireball streak across the sky.

Hunting a rare meteorite

Scientists tracked a fireball across the sky and recovered the fallen meteorite using a network of cameras in the Nullarbor Desert in Western Australia. They also determined its orbit prior to entering Earth's atmosphere. Only a few meteorites have had their orbits traced. The team published its finding in the September 18 issue of *Science*.

The scientists determined that the meteorite's parent body orbited in the inner edge of the asteroid belt between Mars and Jupiter.

The team also analyzed the meteorite's composition and found that, while it's a basaltic meteorite, it's unlike other basaltic space rocks found on Earth. This is one rare space rock. — **L. K.**

BRIEFCASE

The king of planets captured a comet

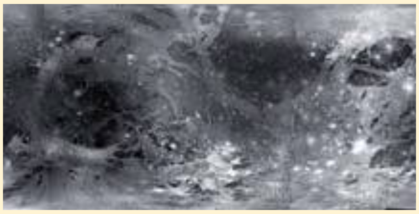
Jupiter captured Comet 147P/Kushida-Muramatsu as a temporary satellite, say astronomers. Between 1949 and 1961, the comet orbited Jupiter, making it only the fifth captured Jupiter orbiter scientists have identified. David Asher of Armagh Observatory in Northern Ireland announced his team's findings September 14 at the European Planetary Science Congress in Potsdam, Germany. — **L. K.**

Our chilly Moon

Astronomers say that craters at the Moon's south pole might be the coldest places in the solar system. Using instruments aboard the Lunar Reconnaissance Orbiter (LRO), scientists found that the temperature in these craters never rises above about –397° Fahrenheit (–238° Celsius). Scientists announced the finding, along with other news about our nearest neighbor, September 17 at a press conference of the first scientific results from LRO. — **L. K.**

Binary star system's mystery solved

Astronomers have solved the slow precession of a pair of stars called DI Herculis. It turns out the stars are tipped over on their sides. As they rotate, they bulge at their equators, like most stars. However, because the stars are tipped, they create unusual tidal interactions, which slow their precession by some 4 times. The finding appeared in the September 17 issue of *Science*. — **L. K.**



Icy geology. Scientists combined images from previous NASA missions to create this global map of Ganymede. Image courtesy Europlanet Media Center

First global map of Ganymede completed

Using images from NASA's Voyager 1, Voyager 2, and Galileo missions, a team of astronomers created a detailed map of the geological features of Jupiter's moon Ganymede. This is only the third time astronomers have completed global maps of solar system moons — the other two maps represent our Moon and Callisto, another of Jupiter's satellites. Wes Patterson of the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, presented the map September 16 at the European Planetary Science Congress in Potsdam, Germany.

With a diameter of 3,273 miles (5,268 kilometers), Ganymede is the solar system's largest satellite. It's also the only moon to have its own magnetosphere.

From the new geological map, scientists can learn about Ganymede's formation and the history of small bodies impacting its surface, then compare these characteristics with other icy satellites. — **L. K.**

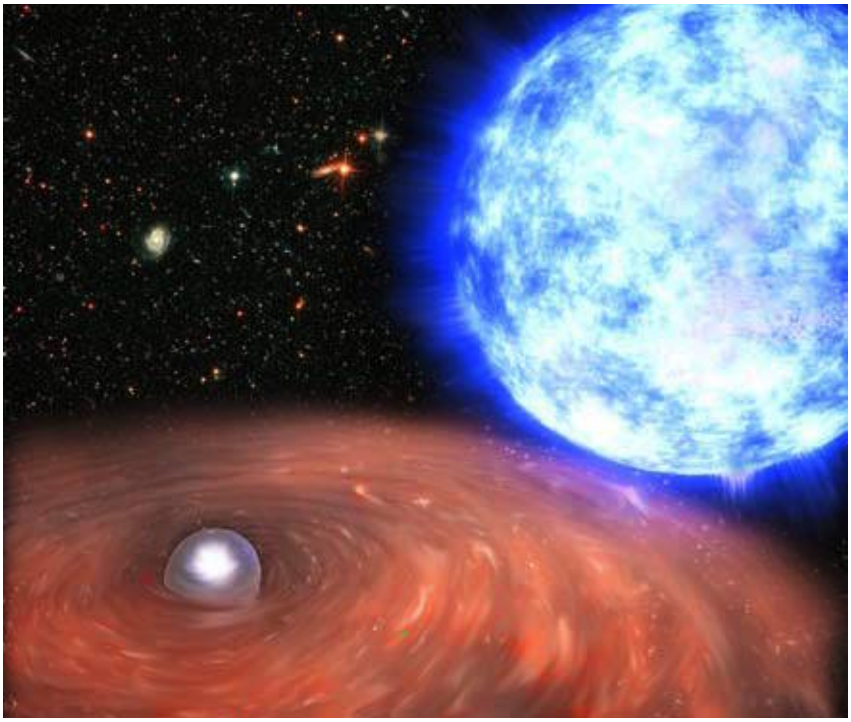
Keep the crusts German scientists announced September 17 at the European Planetary Science Congress that conditions on early Earth could have "cooked" amino acids into important building blocks for life when embedded into salty crusts.

Scientists discover stellar Rosetta stone

A special type of white dwarf star — a small, compact stellar cinder — could help astronomers decipher the inner workings of the circumstances leading up to type Ia supernovae, according to a September 4 paper in the journal *Science*. Scientists using the European Space Agency's XMM-Newton orbiting X-ray telescope determined a mysterious X-ray emitting object was in fact an unusually massive and fast-spinning white dwarf star circling around a companion star.

"This is the Rosetta stone of white dwarfs in binary systems," says lead author Sandro Mereghetti. By studying the precise masses of the two stars, he and his colleagues can measure the white dwarf's increasing mass, likely from the theft of its companion's gas. If the white dwarf, currently 1.3 times as massive as the Sun, grows to 1.4 solar masses, it will either collapse into a neutron star or explode into a type Ia supernova.

XMM-Newton gave astronomers the best method to date for determining the masses of stars. "Our precise determination of the masses of the two stars is crucial," says Mereghetti. "We can now study [the white dwarf] further and try to reconstruct its past so that we can calculate its future." — **B. A.**



Future supernova. This white dwarf, illustrated with its companion HD 49798, acts like a Rosetta stone to astronomers who can study it in unprecedented detail to learn about such systems and their eventual demise. Francesco Mereghetti/NASA/ESA/T.M. Brown (STScI)

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The cosmic web

What galaxy superclusters tell us about the universe

Astronomers are working to understand the universe's large-scale structures — how they formed and how they affect cosmic expansion. **by Bruce Dorminey**

On the largest scales, our universe looks as smooth as the surface of an Alpine lake on a windless afternoon. But on scales of hundreds of millions of light-years or less, the cosmos is a random, confounding pattern of matter and voids. It's a clumpy universe.

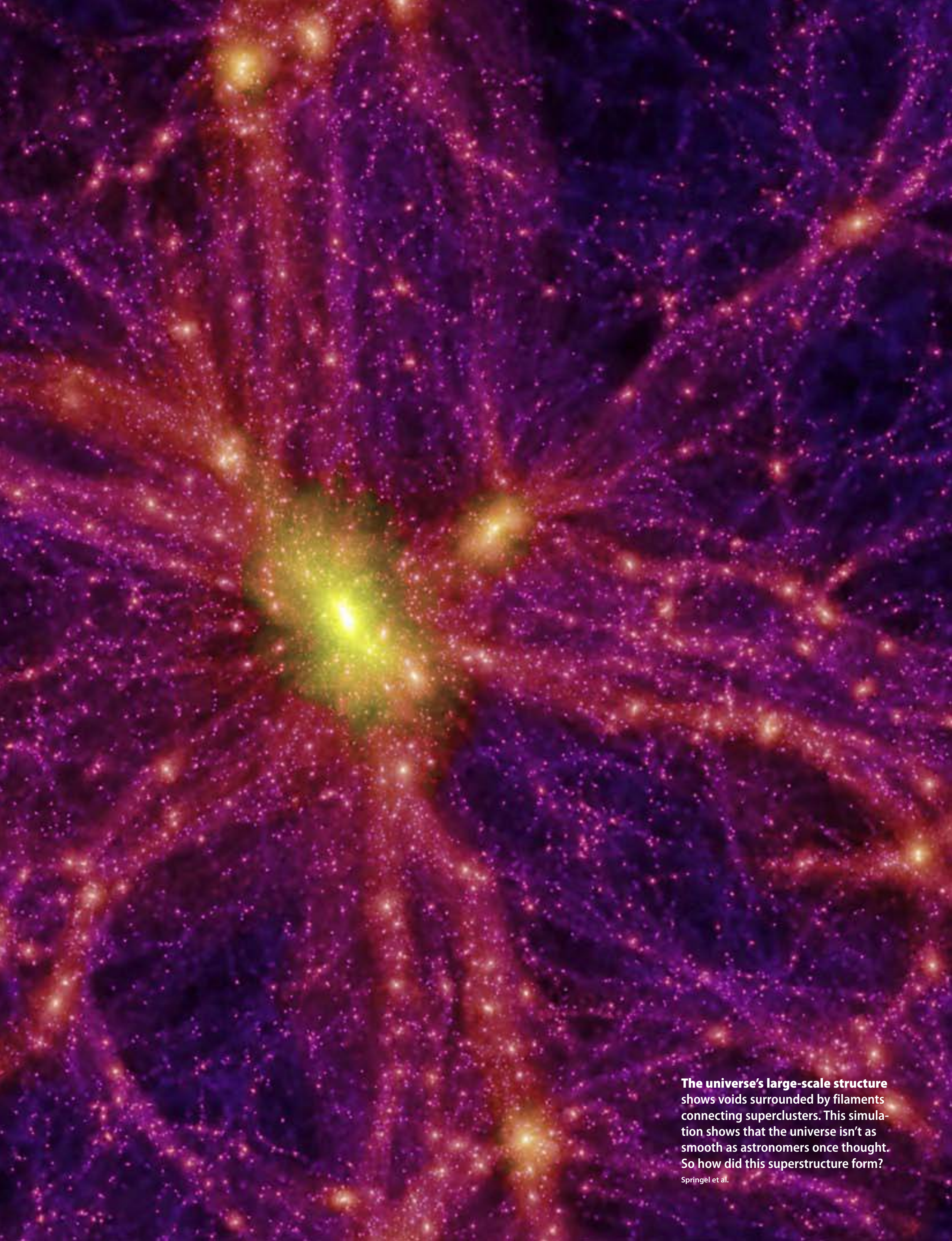
Although voids make up most of the universe's volume, denser regions of long filaments interlace these "empty" areas. Matter is strung along filaments that glisten with galactic pearls, like sunlight reflecting off water caught in a spider's maze. Enmeshed in this cosmic web are individual galaxies, galaxy clusters, and, even more mystifying, agglomerations of galaxy clusters termed "superclusters."

Superclusters usually contain a minimum of eight Abell-type clusters on size scales analogous to the nearby Virgo cluster (a collection of some 2,000 galaxies). In fact, an "average" supercluster normally has upward of 50,000 galaxies within a total diameter of some 200 to 300 million light-years.

It's not just the pattern of galaxy superclusters, but how they form, evolve, and are linked across the sky that bewilder cosmologists. And that's before considering more esoteric aspects of supercluster distribution, such as: What does this seemingly random distribution of cosmic matter tell us about the universe's ultimate nature or our own role in this cosmic sea?

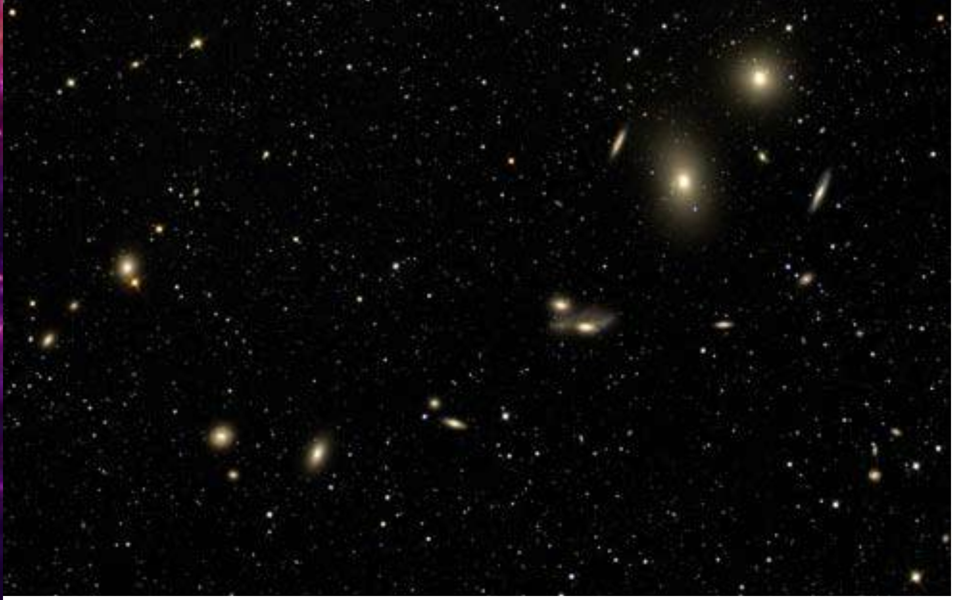
Detecting structure

The first evidence for the existence of superclusters came with the Herschel



The universe's large-scale structure shows voids surrounded by filaments connecting superclusters. This simulation shows that the universe isn't as smooth as astronomers once thought. So how did this superstructure form?

Springel et al.



The Virgo cluster is our nearest galaxy cluster. Along with the Local Group of galaxies, it's also part of our local supercluster. Rich Jacobs

family's nebula surveys in the 18th century. Then, nearly two centuries later, University of California at Los Angeles astronomer George Abell found hints of superclusters while searching for galaxy clusters on the photographic plates of the Palomar Observatory Sky Survey.

Abell subsequently published the first catalog of galaxy clusters. Today, astronomers have cataloged only a few dozen superclusters, although it's estimated that there must be millions of superclusters in the universe.

The study of how superclusters affect the universe's large-scale structure (LSS) has progressed in a piecemeal fashion. Forty years ago, scientists thought the universe was more uniform in all directions, or "isotropic," on larger scales than it actually is. In the past 3 decades, cosmologists have served up observational fan-shaped images of the deep sky that show the universe is nonisotropic.

Looking at superclusters from afar is akin to trying to delineate cities within the Northeast Corridor, says astronomer Brent Tully of the University of Hawaii. He adds that their boundaries can be rather arbitrary because filaments typically link them over large portions of the sky.

It's hard to envisage the scope of a supercluster, and it's even more difficult to imagine how this LSS stretches the fabric of space-time. But superclusters are organized on scales of tens to hundreds of millions of light-years. Cosmologists believe the initial ripples and fluctuations in the fabric of the early universe are the seeds that formed modern-day clusters and superclusters.

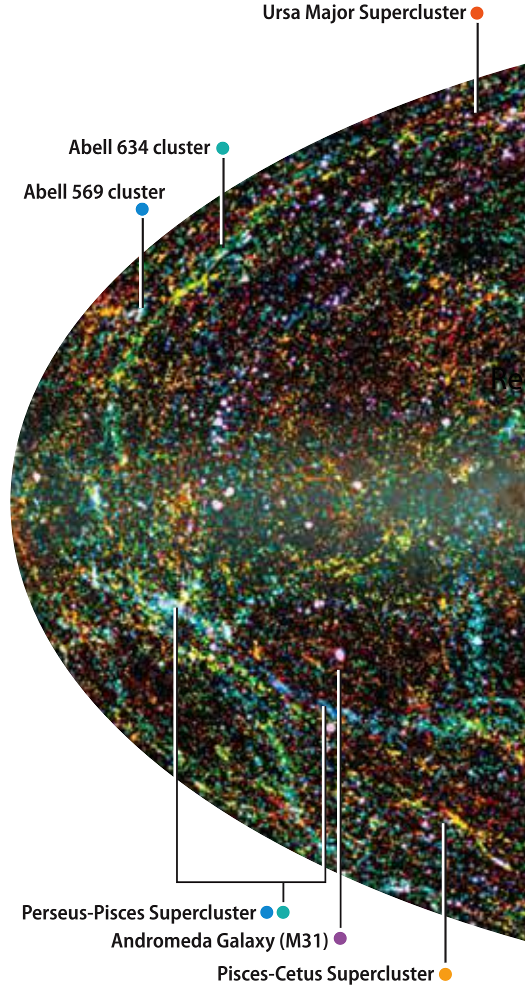
Bruce Dorminey, *a frequent contributor to* Astronomy, *is a science journalist and author of* Distant Wanderers: The Search for Planets beyond the Solar System *(Springer, 2001).*

"When the young universe was very hot, the embers of these superstructures appeared as early perturbations that were just random fluctuations in the very early medium," says astrophysicist Jaan Einasto of Tartu Observatory in Estonia. "Later, when matter started to collect in places where the density was higher, gravity took over. But in the early stages, the fluctuations were [already] there."

Looking at superclusters from afar is akin to trying to delineate cities within the Northeast Corridor.

The planned Australian Square Kilometer Array Pathfinder (ASKAP) will allow for the wide-field detection of neutral hydrogen gas, which is a fundamental building block of all galaxies. By tracing the hydrogen gas, cosmologists can view early structure. The next-generation radio telescope, now under development, should allow astronomers to trace the formation of the earliest superclusters. ASKAP researchers expect the system, located in western Australia, will be fully operational in 2013.

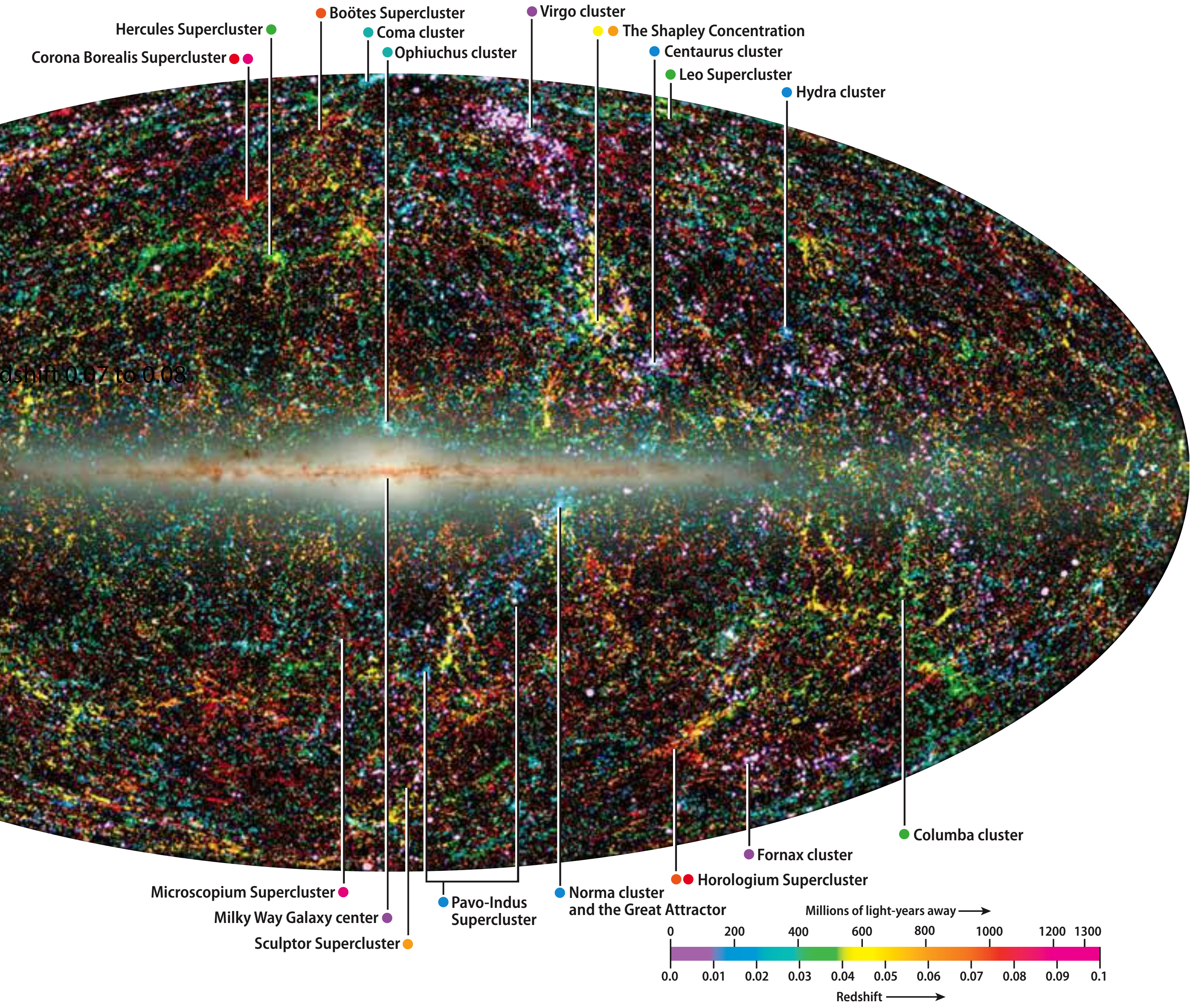
Large-scale structure in the local universe



Some 1.6 million galaxies are plotted in this Two Micron All-Sky Survey (2MASS) panoramic view of the entire sky. The brightest and nearest galaxies are purple and blue, and the faintest and farthest are red. This gives information about the universe's 3-D structure. 2MASS/T. H. Jarrett, J. Carpenter, & R. Hurt

Heath Jones, a research astronomer at the Anglo-Australian Observatory headquartered outside Sydney, wants to obtain redshifts for the galaxies that ASKAP will find. Because redshifts are measurements of velocity, they're inherently due to the stretching of space-time. So, as Jones notes, such measurements may allow researchers to trace the evolution of superclusters through cosmic time. Jones will then look for a causal relationship between neutral hydrogen gas and galaxy formation.

Galaxy clusters such as the nearby Virgo cluster collapse under their own gravity within a billion years of the


Hercules Supercluster
Corona Borealis Supercluster
Boötes Supercluster
Coma cluster
Ophiuchus cluster
Virgo cluster
The Shapley Concentration
Centaurus cluster
Leo Supercluster
Hydra cluster
dshift 0.07 to 0.08
Columba cluster
Fornax cluster
Horologium Supercluster
Microscopium Supercluster
Milky Way Galaxy center
Sculptor Supercluster
Pavo-Indus Supercluster
Norma cluster and the Great Attractor
Millions of light-years away
0
200
400
600
800
1000
1200
1300
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0.07
0.08
0.09
0.1
Redshift

onset of their formation. Superclusters, however, are still in the process of expanding and forming. In fact, superclusters are so big, says Tully, that they haven't had time to collapse over the age of the universe. Although their cores may collapse, he says, their outer regions don't seem to follow suit.

Walls and voids

Even though superclusters are massive, they are not the universe's largest single gravitational entity, says John Huchra of the Harvard-Smithsonian Center for Astrophysics. "The biggest things, which appear to be causally connected, are these giant walls of galaxies," says Huchra, "even though some voids also get to that size." Superclusters, clusters, and individual galaxies make up walls.

The basics of supercluster structure were already evident some 30 years ago. That's when, in 1977 at the first conference on LSS in Estonia, Einasto coined the term *cellular structure* to describe low-density regions surrounded by superclusters and filaments. Only later, he says, did astronomers begin using the term *cosmic web*.

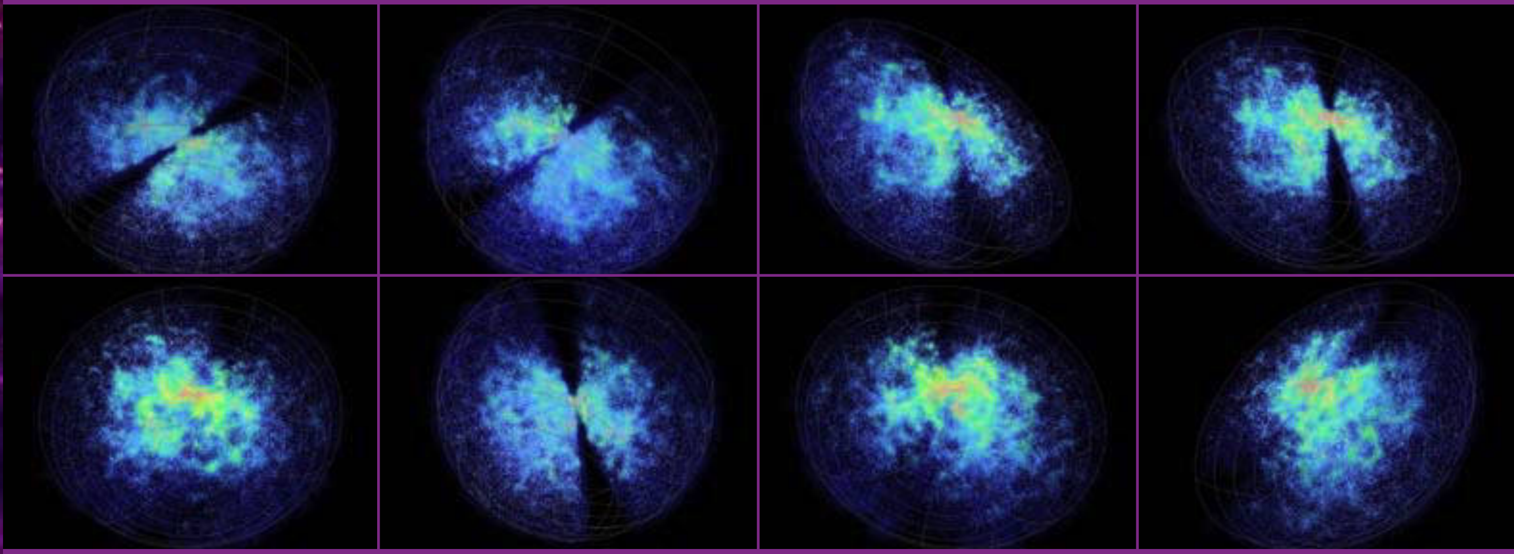
Galaxy formation starts from the densest places in the universe, such as the centers of the richest superclusters. This is where matter is dense enough to start star formation. And the farther from the center of a supercluster you go, says Einasto, the less dense it becomes.

"When we started work in the mid-1970s," says Einasto, "there was a great debate among astronomers about whether superclusters were just randomly located clusters which had surrounding density enhancements." But after the 1977 conference, scientists agreed that superclusters were real physical systems. Einasto and colleagues say they have since confirmed that all galaxies are members of systems. Even independent field galaxies residing in voids are not truly isolated, says Einasto, but rather part of faint galaxy systems.

Moving massive clumps

And although all are part of the never-ending cosmic web, the dynamics of

A survey of the southern sky



Different views of the Six-Degree Field Galaxy Survey (6dFGS) show the 3-D structure of our nearby universe. The 6dFGS observed 80 percent of the southern sky and gathered data on more than 125,000 galaxies. Researchers then created this 3-D map. The wedges are where the galactic plane falls — there's too much dust through which to observe distant galaxies. Chris Fluke, Centre for Astrophysics & Supercomputing, Swinburne University of Technology, using S2PLOT

both their individual constituents and the superclusters themselves are constantly on the move. For example, over large scales superclusters can distort a galaxy's movement due to the outward expansion of the universe (called the "Hubble Flow"). It's not unlike a rock disrupting the flow of a cold mountain stream. Thus, galaxies flowing toward superclusters sometimes interrupt the Hubble expansion on a local scale. The expansion instead appears to move toward us (or "blueshifts").

In the late 1980s, says Jones, astronomers were interested in how galaxy motions as a whole were moving. They subtracted the factor marking the universe's expansion to obtain the local galaxies' "peculiar" velocities. In other words, astronomers were able to record the motions of galaxies with respect to other galaxies, or even the universe's background radiation. As an example, the Milky Way Galaxy's motion within our Local Group of galaxies is made up of three different layers.

On the local scale, we lie along a filament that defines a wall around a void. "Voids are the flip sides of superclusters," says Tully. "Our galaxy happens to lie on the wall of an expanding cavity, in a filament that creates a wall around the local void. We have found a very large motion away from this local void, with our galaxy making a sideways motion away from the void's center." In the largest sense, gravity causes matter to move out of the voids toward nearby superclusters.

On the intermediate scale, we are pulled toward the nearest big concentration of matter, the Virgo cluster, some 55 million light-years away. This cluster is part of a large supercluster, called the Virgo Supercluster.

And on a larger scale, an even larger supercluster, sometimes referred to as the Norma-Hydra-Centaurus Supercluster, is pulling us. Our Local Group and the Virgo Supercluster are appendages of this supercluster.

Gravity causes matter to move out of the voids toward nearby superclusters.

The Norma-Hydra-Centaurus Supercluster, in turn, is being gravitationally pulled toward the Shapley Concentration, some 600 million light-years away in the southern constellation Centaurus. The Shapley complex is roughly 4 times more massive than the Virgo Supercluster and is the highest density supercluster known.

Huge surveys required

One tool for better determining supercluster dynamics continues to be surveys of large sky tracts. The recently completed Six-Degree Field Galaxy Survey (6dFGS) in Australia covered 17,000 square degrees, or 80 percent, of southern sky, giving the most detailed view yet of southern large-scale structures. Although the observing team is still analyzing the data, it reports that 6dFGS has obtained redshifts for some 125,000 galaxies, including more than 400 Abell galaxy clusters in the southern sky.

"The main way people find clusters is with the Friends of Friends (FoF) algorithm," says Jones, a co-investigator on the 6dFGS. "Take a galaxy and look around it for neighboring galaxies, and then search around those for secondary galaxies. When you run out of neighboring galaxies, you define that as a group."

But progress in surveying large swaths of the sky at great depths has inherently been a painstaking process. "Fifty years ago, astronomers didn't have any idea about the distribution of galaxies in general," says Einasto. "Now we know both galaxies and galaxy clusters collect in high-density regions. Superclusters are not [just] a cluster of clusters, but rather a high-density region inside this cosmic web."

Tully says that in the near-term, data from the 6dFGS and the James Webb Space Telescope (scheduled for launch in 2014) will play a role in better understanding superclusters. And there still aren't any simulations that can reproduce superclusters in detail. To improve such computer simulations, astronomers need better observational data. A 6dFGS for the northern sky would help.

A new survey whose prototype telescope saw first light in 2006 will help as well. The University of Hawaii-led Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) will be the largest wide-field optical survey to date, surveying 75 percent of the sky once it's fully operational in 2013. Pan-STARRS will be a tremendous boon for delineating the 3-D structure of galaxies within some 5 billion light-years, and therefore the surrounding LSS.

Self-similar cosmos?

What difference does it make that 90 percent of the universe appears to consist of voids, while the remaining 10 percent seems to be filaments and superclusters? The answer may lie in "fractality." Although deep surveys like Pan-STARRS should give a global picture of how superclusters actually are distributed across the sky, Tully says that on relatively large local scales (between 100 and 300 million light-years), the universe is rife with fractal patterns.

Fractality in its simplest form is a mathematical method of describing a nonuniform shape that looks the same at different distances, says mathematician Benoit Mandelbrot, the recognized "father of fractalism." Fractalism inherently involves infinitely complex yet self-similar structures. Examples include the branching structure of trees, coral reefs, the human vascular system, coastlines, stone and metal fragments, mountain chains, snowflakes, and superclusters. And even if the patterns reveal nothing about these structures' means of formation, fractality does offer a novel way of looking at how the cosmos is organized.

"Years ago, the cosmologists said my fractal models don't apply," says Mandelbrot, retired from IBM's Thomas J. Watson Research Center and Yale University. "But now they've changed their minds and said that the models don't apply to the infinitely small and infinitely large."

Yet if the universe is infinite, as some cosmologists now believe, Mandelbrot thinks fractality also ultimately may be proven to extend to infinite scales, although that's a view not held by most cosmologists. But when Mandelbrot looks at the surface of a fractured rock and then a slice of the cosmos, it tells him the universe has order.

"There are laws of nature that apply under extremely different conditions," says Mandelbrot. "Nature is ruled by the big equations of mathematical physics. Things that seem to be completely irregular are, in fact, very regular. So, there is some big principle of organization in our universe from one scientific discipline to another." Beyond that, Mandelbrot refuses to speculate about what sort of physical laws might create fractal similarities on such incongruous scales.

Fractals exist throughout nature — in snowflakes, ferns, crystals, and coastlines. Some scientists think the universe's large-scale structure could also exhibit fractalism. Kenneth Libbrecht

The big picture

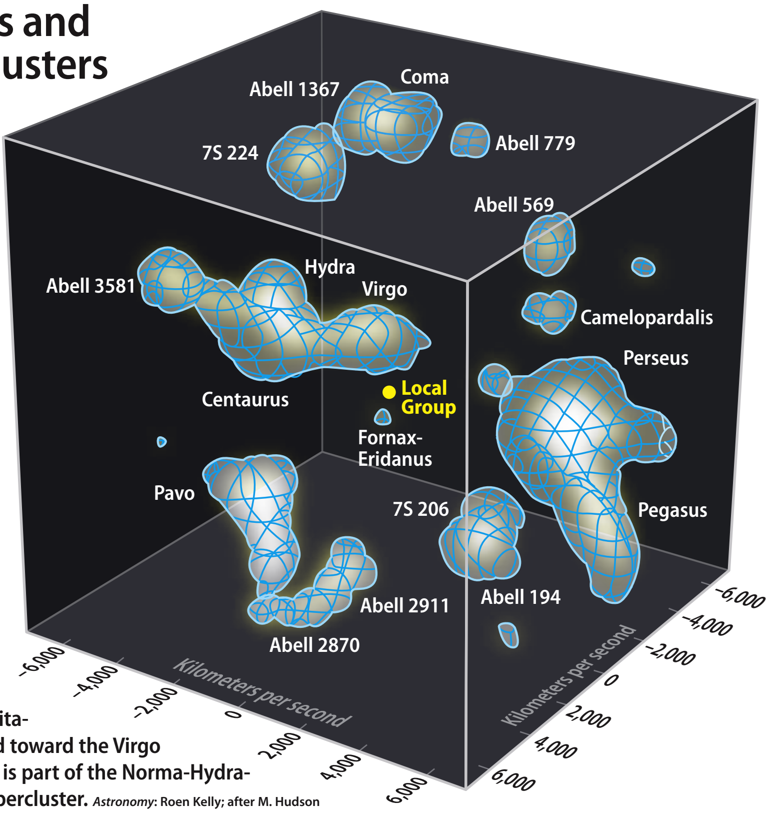
Those willing to think about the universe in philosophical terms are left struggling to connect the organizational dots between the largest structures in the universe and the lowliest rock fragments. Even so, both theorists and observers will continue to await deeper observational surveys along with more comprehensive computer simulations to help them understand at least two other quandaries.

Will LSS ever be truly comprehensible? Will we ever understand the impact LSS has had on life's formation?

Huchra believes details about how the universe's LSS formed, evolved, and is ordered will become clear within a matter of decades. But "the connection between the universe's large-scale structure and life on Earth will take a lot longer to understand," he says.

In the interim, the fine points of the universe's organizational structure will likely remain inscrutable. ◑

Clusters and superclusters nearby



Our Local Group is gravitationally pulled toward the Virgo cluster, which is part of the Norma-Hydra-Centaurus Supercluster. *Astronomy*: Roen Kelly; after M. Hudson

Fly through the 6dFGS at www.Astronomy.com/toc.

What was the **Star of**

Astronomy can rule out several candidates for the sight that appeared to the wise men — but it can't eliminate them all. **by Michael E. Bakich**

Some 2,000 years ago, a heavenly event took place that still has profound meaning for billions of people around the world. Each year as December 25 draws near, astronomers, planetarium staffs, and science writers often hear this question: "What was the Star of Bethlehem?" Could it have been a brilliant fireball streaking through the sky or perhaps a long-lived comet or supernova?

Barring a miraculous explanation, astronomical science can offer several possibilities for the sky phenomenon that appeared. The factual basis is certainly meager, but the outstanding importance of the birth of Jesus of Nazareth encourages us to examine the evidence in light of past astrological and current astronomical knowledge.

When we try to associate the Star of Bethlehem with a natural event, we encounter a problem: Historians don't know the exact day or year in which Jesus' birth occurred.

Not just another day

And there were in the same country shepherds abiding in the field, keeping watch over their flock by night.

And, lo, the angel of the Lord came upon them, and the glory of the Lord shone round about them: and they were sore afraid.

And the angel said unto them, Fear not: for, behold, I bring you good tidings of great joy, which shall be to all people. For unto you is born this day in the city of David a Saviour, which is Christ the Lord. (Luke 2:8-11)

The story of the shepherds watching their flocks by night gives us a strong clue about the time Jesus was born. Since earliest times, December and January have been rainy and cold in Bethlehem, a time when all sheep are in corrals. Only in February, March, and April, when spring lambs are born, do the shepherds of Judea watch their flocks by night. In December, the shepherds were more likely to be sitting home by their fires.

Shepherds tend their sheep in the spring, when lambs are born, just like 2,000 years ago in Judea. Historians thus conclude that Jesus was not born December 25.

Yet we celebrate Christmas on December 25, near the start of the winter season. Most early churches accepted this date because Pope Julius I had proclaimed it in A.D. 350. He based his proclamation partly on the common belief that the date Jesus' Incarnation occurred was March 25. This implied that the birth of Jesus took place 9 months later, on December 25.

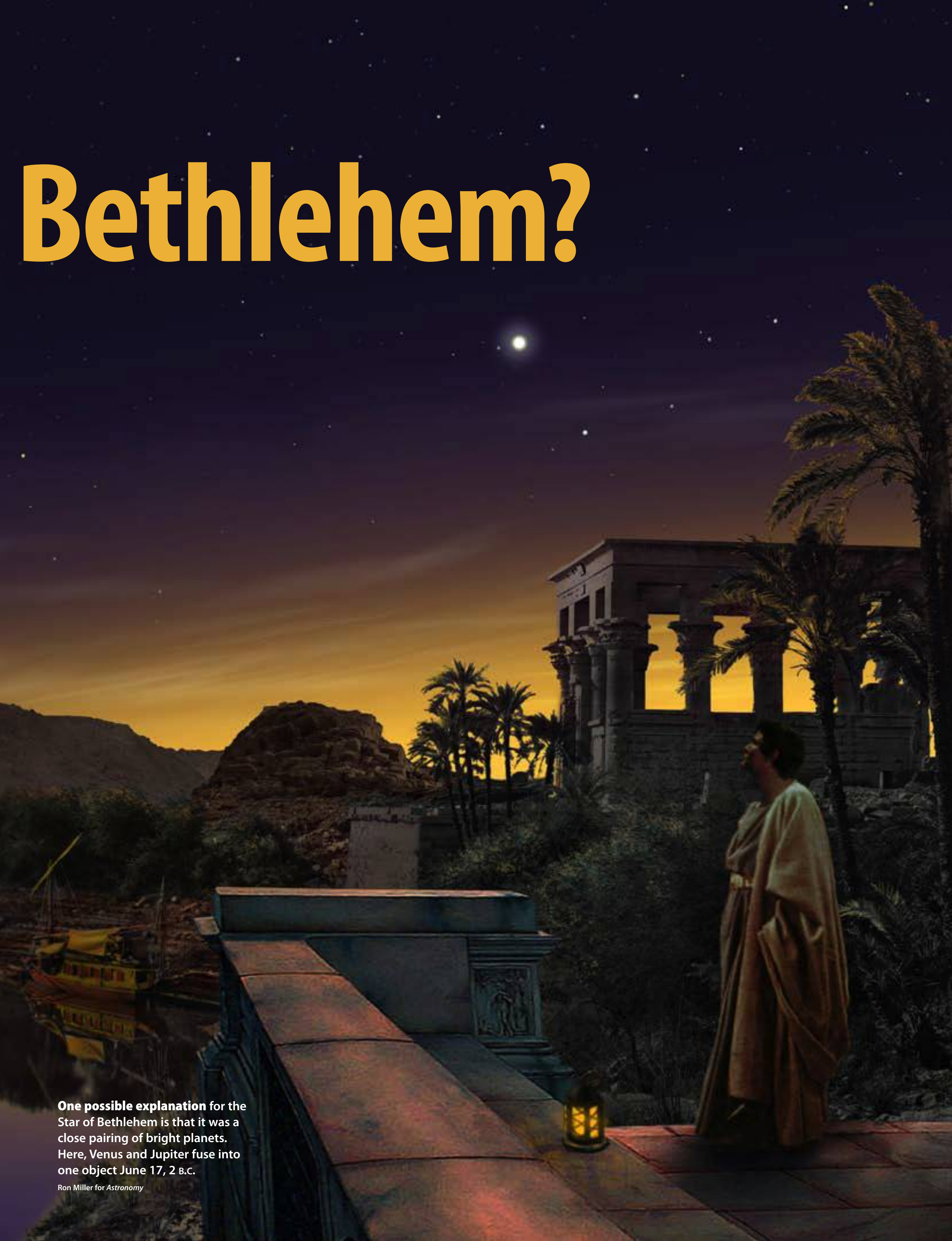
But Julius may have had other reasons. In choosing December 25, he changed the date of the Christmas celebration from January 6. Presumably, he did this to avoid Christmas coinciding with a pagan celebration. However, by choosing December 25, Julius picked the date of an even greater non-Christian holiday, that of Sol Invictus — the birthday of the Sun.

Around this date, people held celebrations in observance of the end of the Sun's southerly movement in the sky. This was a time of great joy because after this date the Sun appeared a bit higher with each passing day. The community celebrated this return of light — and thus life — by exchanging gifts, decorating homes, and dancing in the streets. All the hoopla probably made it easier for early Christians — forced to worship in secret — to celebrate Jesus' birth without attracting attention. So, when Julius chose December 25 as Christmas, he likely suspected that people would adopt many of the existing seasonal practices.

The first Christmas

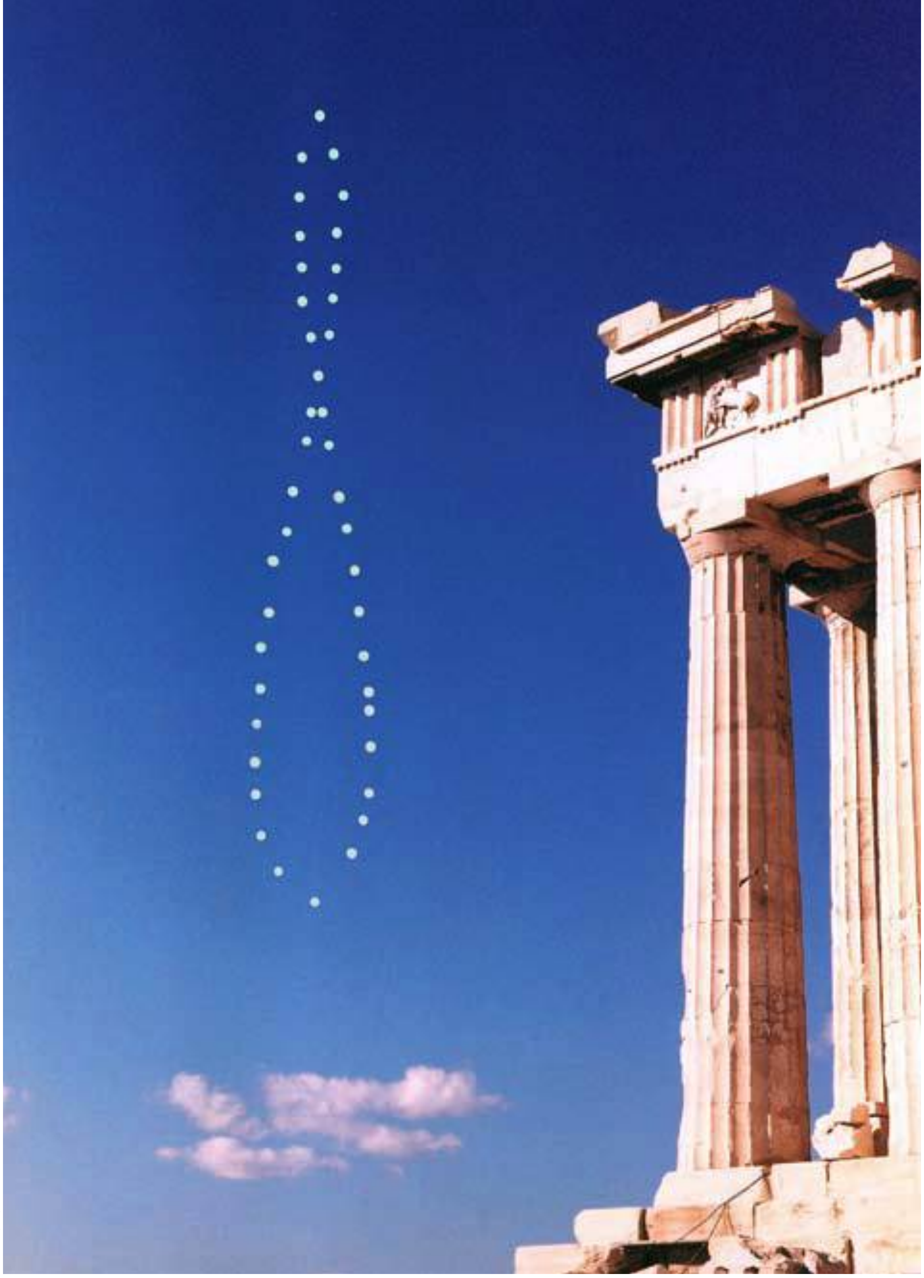
And it came to pass in those days, that there went out a decree from Caesar Augustus that all the world should be taxed. (And this taxing was first made when Cyrenius was governor of Syria.) And all went to be taxed, everyone into his own city. And Joseph also went up from Galilee, out of the city of Nazareth, into

Bethlehem?



One possible explanation for the Star of Bethlehem is that it was a close pairing of bright planets. Here, Venus and Jupiter fuse into one object June 17, 2 B.C.

Ron Miller for *Astronomy*


Anthony Ayiomamitis

This analemma, which shows the Sun's path throughout an entire year, graphically illustrates how our daytime star's altitude changes. After it reaches its lowest point (winter in the Northern Hemisphere), the Sun begins to move northward again. In ancient times, this was cause for celebration.

Johannes Kepler developed the three laws of planetary motion. Based on an account of a lunar eclipse near the death of King Herod, Kepler proposed that the birth of Jesus had occurred prior to 4 B.C. copy of anonymous 1610 portrait

Judea, unto the city of David, which is called Bethlehem; (because he was of the house and lineage of David). To be taxed with Mary his espoused wife, being great with child. (Luke 2:1-5)

This passage from Luke's gospel tells us Jesus was born after Joseph and Mary went to Bethlehem to pay their taxes. If we can identify this year, we'll know when Jesus was born.

At the time of this taxation, Judea used the Roman calendar, which counted years from the founding of Rome. Our present calendar presumably starts with Jesus' birth as calculated by the Scythian monk Dionysius Exiguus around A.D. 533. Historians differ concerning the year to which Dionysius referred. Most place it at 1 B.C., but others calculate A.D. 1.

One person who claimed a different year was German astronomer Johannes Kepler, who gave astronomy the three laws of planetary motion. Kepler said Jesus was born during the reign of Herod the Great, whose death he placed at 4 B.C. Kepler made this statement because the Jewish historian Flavius Josephus claimed that a lunar eclipse had occurred shortly before Herod's death. Other eclipses, however, could fit Josephus' statement. One occurred December 29, 1 B.C.

The taxation gives us another clue. In 1923, archaeologists digging near Ankara, Turkey, discovered the ruins of an old Roman temple on whose wall they found an inscription describing three empire-wide tax collections, one of which occurred in 8 B.C.

In those days, word of the taxation traveled by couriers. It may have taken several years for word to reach the distant parts of the empire.

And so it was, that, while they were there, the days were accomplished that she should be delivered. And she brought forth her firstborn son, and wrapped him in swaddling clothes, and laid him in a manger; because there was no room for them in the inn. (Luke 2:6-7)

Because Herod was alive when the wise men came to Jerusalem, Jesus must have been born after the taxation order of 8 B.C. and before Herod's death, perhaps as late as 1 B.C. From the mention of the slaughter of the innocents in Matthew, we know that Jesus was around 2 years old when Herod died. So, according to the calendar we now use, Jesus was born several years B.C.

Enter astronomy

Now when Jesus was born in Bethlehem of Judea in the days of Herod the king, behold, there came wise men from the east

---

Michael E. Bakich *is a senior editor of* Astronomy.

to Jerusalem, Saying, Where is he that is born King of the Jews? for we have seen his star in the east, and are come to worship him. When Herod the king had heard these things, he was troubled, and all Jerusalem with him. And when he had gathered all the chief priests and scribes of the people together, he demanded of them where Christ should be born.

And they said unto him, In Bethlehem of Judaea: for thus it is written by the prophet, And thou Bethlehem, in the land of Juda, art not the least among the princes of Juda: for out of thee shall come a Governor, that shall rule my people Israel. Then Herod, when he had privily called the wise men, enquired of them diligently what time the star appeared. And he sent them to Bethlehem, and said, Go and search diligently for the young child; and when ye have found him, bring me word again, that I may come and worship him also. When they had heard the king, they departed; and, lo, the star, which they saw in the east, went before them, till it came and stood over where the young child was. When they saw the star, they rejoiced with exceeding great joy. (Matthew 2:1-10)

The biblical account says the wise men spoke to Herod about the star. Neither Herod nor his scholars knew what they were talking about. No other Bible verse or secular writing mentions the star. What was it?

Could it be that Matthew, the only gospel writer who mentions the star, wanted to prove to his readers what he knew from reading the Old Testament?

I shall see him, but not now: I shall behold him, but not nigh: there shall come a Star out of Jacob, and a Sceptre shall rise out of Israel … (Numbers 24:17)

Did the writer of Matthew invent a story to fulfill this prophecy from Moses? Most historians don't think so.

Some writers have suggested that the astronomical event called a star may have been a brilliant meteor, also known as a fireball. This explanation is the least likely because meteors — even bright ones — disappear in mere seconds. The star the wise men saw, on the other hand, remained in the sky for months.

Bright comets can be long-lived phenomena. (Anyone remember Hale-Bopp?) Since ancient times, however, people have regarded comets as harbingers of doom. Around the time of Jesus' birth, scholars would have interpreted a comet as the finger of God (or of a god) pointing to Earth, warning of a disaster soon to befall.

Perhaps a supernova was the sky sign the wise men followed to the birthplace of Jesus. Supernovae signal the deaths of massive stars, and some have blazed brightly through the years.

In 1054, a supernova became visible near one of the horns of the constellation Taurus the Bull. Observers followed this event — which created the Crab Nebula — for 2 years with their naked eyes. Moreover, for 3 weeks around its maximum brightness, the supernova was visible during the daytime.

Most sources discount the possibility of the star being a supernova because nothing but the book of Matthew records it. Writers say it seems implausible that Eastern astrologers, especially the Chinese, would have missed recording such a bright natural event as a supernova.

The earliest written record of a supernova, however, dates back only to A.D. 185. In that year, the Chinese recorded a bright "guest star" in an asterism they called Nanmen. The supernova's position lies in the present-day southern constellation Centaurus.

Therefore, while a bright supernova might have been visible to much of the world's population, no record exists of one around the first Christmas. This fact reduces, but does not rule out, such an event as a possibility for the star.

Team of rivals

Astronomers decry the practice of astrology because of the lack of scientific validity in its predictions. However, to identify the celestial sign the wise men may have seen, scientists and historians need to interpret astronomical events in the light of ancient astrological knowledge.

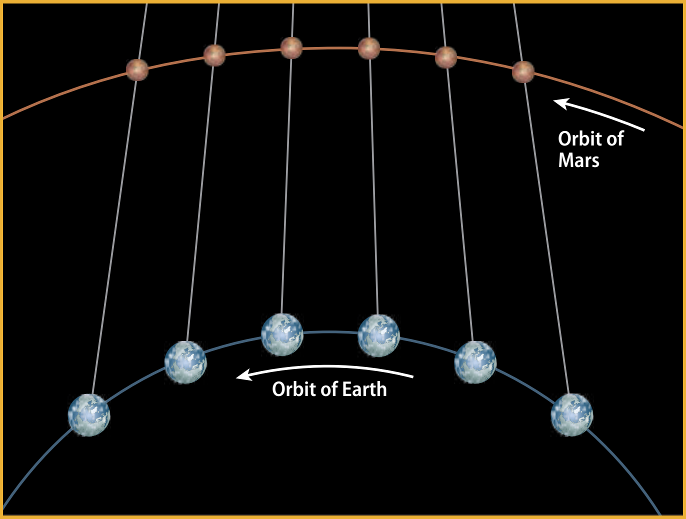
The wise men came from the east to Jerusalem. We often refer to them as

A fireball — any meteor brilliant enough to cast a shadow, like the two on the right side of this image — would not have been visible for long. Because meteors have short durations, scientists can rule out such events from consideration for the Star of Bethlehem. Tony and Daphne Hallas

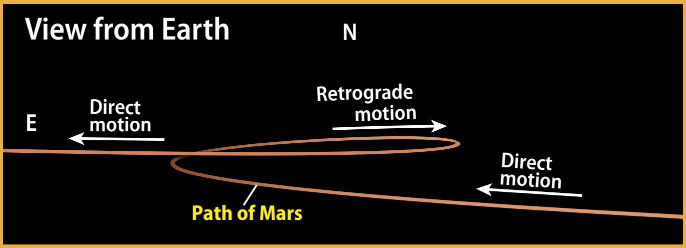
Comet Hale-Bopp blazed for months in 1997 and was visible even to those who lived in cities. In ancient times, astrologers considered comets bad omens. No one, therefore, would have interpreted one as the sign a savior had been born.

Frans Klauser

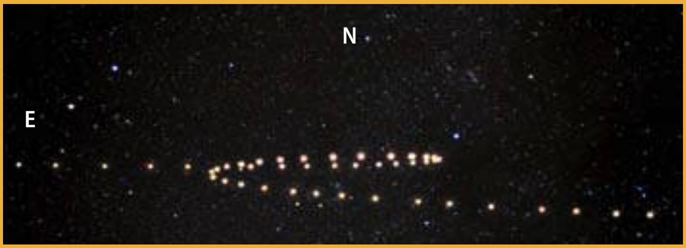
When planets move backward



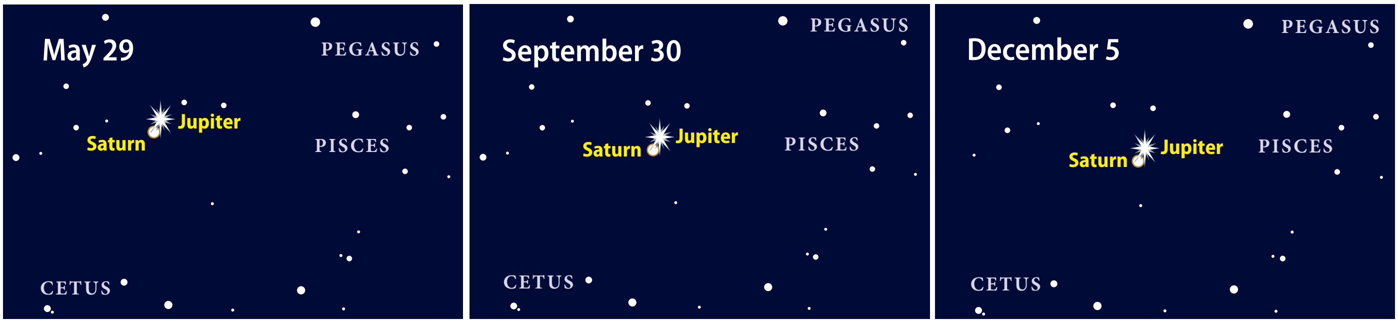
Retrograde motion, which can cause planets to undergo triple conjunctions with other planets, occurs when Earth, moving faster in its orbit, passes a more distant planet. From our perspective, the planet appears to reverse direction against the starry background. Holley Y. Bakich



One result of Earth passing a more distant planet (as in the illustration to the left) is a loop similar to this one. *Astronomy*: Roen Kelly



Mars demonstrates retrograde motion in this image that combines 44 separate exposures. The photographer took the first one (recording Mars as the bright dot farthest to the right) August 19, 2007. He acquired the final image (far left) May 3, 2008. Tunç Tezel



A triple conjunction of Jupiter and Saturn occurred in 7 B.C. At first glance, these illustrations look the same, but compare the positions of the planets with the background stars. On May 29, Jupiter passed Saturn (both moving right to left) for the first time. Jupiter passed Saturn again September 30 with both moving to the right (west). Finally, the planets resumed eastward motion, and Jupiter passed Saturn for the third time December 5. *Astronomy*: Roen Kelly

"magi," from which we get our words "magic" and "magician." They were priests, soothsayers, or astrologers, perhaps adhering to the Zoroastrian faith.

Such men thought the positions of the Sun, Moon, and planets against the background stars controlled the world's fate. They believed that correctly interpreting such "signs" would reveal the future.

Today, anyone with desktop planetarium software can calculate the positions of the planets thousands of years ago. If you do, you'll discover two events, one involving Jupiter and Saturn and the other between Jupiter and Venus, that might have attracted the magi's attention.

Astronomers refer to each of these gatherings as conjunctions. Two planets form a conjunction when, as seen from Earth, they appear closest in the sky.

Dance of the planets, part 1

The first of these events began in late May of 7 B.C., as Jupiter passed Saturn for the first of three times (called a triple conjunction), all in Pisces the Fishes.

The ancients thought Jupiter was a lucky object and a royal star, named as it is after the king of the gods. Saturn had special significance as a protector of the people living in the eastern Mediterranean region. And astrologers believed celestial events occurring in Pisces foretold important earthly events occurring in the land of the Hebrews.

The Biblical passage says the star was in the east. The Greek word used has a specific meaning — that of the morning appearance of a star. The God's Word translation says, "We saw his star rising and have come to worship him."

So when Jupiter and Saturn first met in Pisces in the eastern morning sky, the magi might have considered a journey to Jerusalem. But summer in the Middle East is not a time for difficult journeys.

After several weeks, Jupiter and Saturn stopped moving eastward and moved backward. Today we know this effect happens when Earth, in its orbit, passes any outer planet.

Because Jupiter lies closer to Earth, it moved faster and appeared to pass Saturn a second time in late September. If the magi regarded this sign to begin their pilgrimage, they may have arrived in Jerusalem in late November after several months on a well-traveled caravan route.

There they asked King Herod where they might find the child who was born to be king of the Jews. The conversation

Some historians propose that a supernova, like 1987A — the bright star in the center of this image — heralded the birth of Jesus. Astronomical science cannot rule out this possibility. Marcelo Bass, CTIO/NOAO/AURA/NSF

The Crab Nebula (M1) in Taurus the Bull is an expanding supernova remnant created in 1054 when a star exploded. The dying star became so bright that it was visible for 3 weeks in daylight. Brian Lula

led them to Bethlehem, and, in early December, Jupiter and Saturn came close together in Pisces for the third time. As the magi traveled south on the road from Jerusalem to Bethlehem, the two planets would have appeared directly ahead of them in the sky.

Dance of the planets, part 2

The second planetary conjunction that may have inspired the magi was even more spectacular. In early August 3 B.C., Venus sat high in the eastern sky at sunrise. As the days passed, the magi would have observed Jupiter emerging from the dawn glow and approaching Venus.

Around 4 A.M. August 12, Jupiter was in conjunction with Venus. The two objects stood 0.1° apart, only about one-fifth the Full Moon's diameter.

At the same time, the Sun, the Moon, and Mercury were in Leo the Lion. The ancients saw Leo as the house of Judah, the Jewish tribe prophesized as the one from which the savior would come.

In early September, Mercury joined Venus while the Sun entered Virgo the Maiden. These events would have caught the attention of any astrologer because the prophecy said a son would be born of a virgin and be a descendant of Judah, and a messenger would introduce him.

As Venus and Mercury approached the Sun, Jupiter was moving toward Leo's brightest star, Regulus. Jupiter, heading east, passed Regulus September 12 and then, on December 1, stopped and began moving westward, back toward Regulus. It passed that star again February 17, 2 B.C. The two met a final time May 5.

King of conjunctions

But the best was yet to come. Only one month later, Venus headed for Jupiter again. The pair of brilliant planets drew closer until the evening of June 17. Just after sunset, these two gods fused into one object — a sight no one alive had ever seen. Is it possible that this conjunction inspired the magi to begin their journey to Judea?

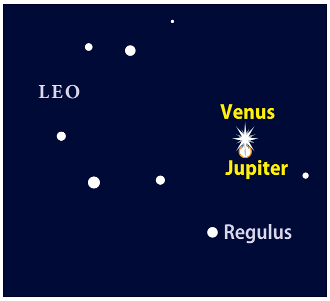
These conjunctions all sound plausible, but they still fail to fit all aspects of the account. Why would the writer of Matthew use the word "star" when two or more planets were involved? How did the star disappear and later reappear, causing the magi to rejoice?

The account in the book of Matthew says the star "came and stood over where the young child was." Astronomical calculations show that these planets never stood overhead anywhere in Judea around the time of Jesus' birth.

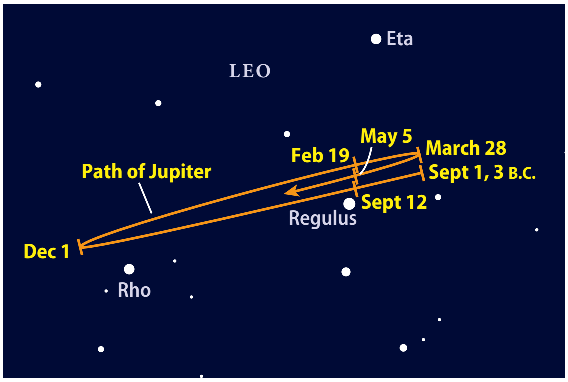
The basis for an astrological explanation is on shaky ground. Herod and his advisers believed in astrology. How, then, were they in the dark about an easily viewed conjunction of planets?

Also, why would the book of Matthew refer to astrology, a false and forbidden belief? The Old Testament contains many exhortations to the Jews to avoid astrology. Interpreting those words as astrological, therefore, would be inconsistent with biblical thought.

Discussions of the Star of Bethlehem have existed for hundreds of years. But no matter what it may have been, the sign that appeared in the sky to the magi that first Christmas will always have deep meaning to billions of people. For with it came a promise of peace on Earth. As we gaze toward the sky this holiday season with naked eyes, binoculars, or a telescope, that's a good thought to have.



Venus and Jupiter made a close pair August 12, 3 B.C. In the predawn sky, skywatchers would have seen Venus only 0.1° from Jupiter just west of the Sickle asterism in the constellation Leo the Lion. Both planets stood 6° west-northwest of Regulus. *Astronomy*: Roen Kelly

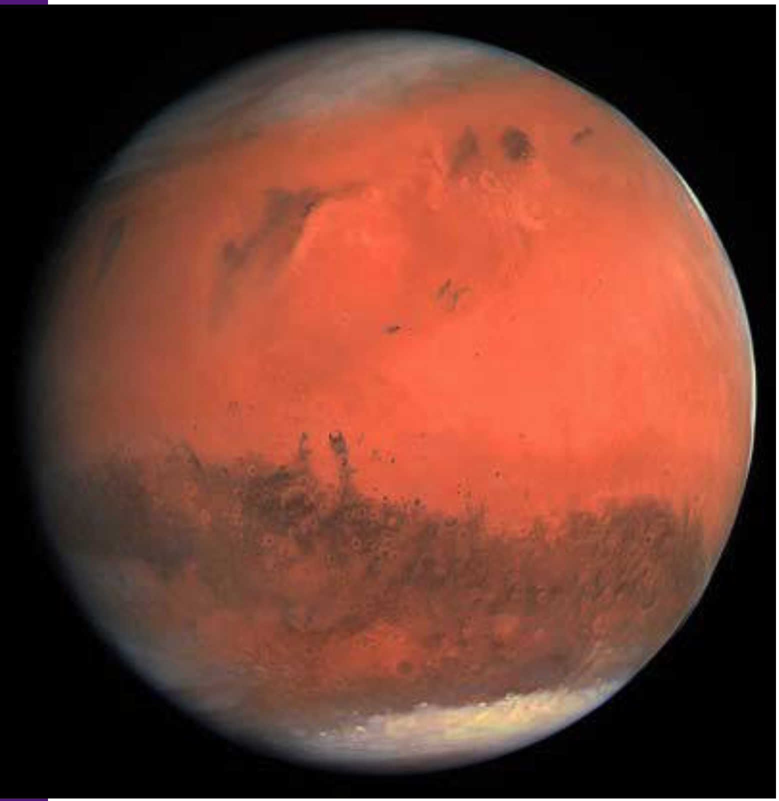


Planets and stars also can pair up for triple conjunctions. In 3 B.C., Jupiter, moving eastward, passed Regulus (Alpha [α] Leonis) September 12. The following year saw two additional pairings of the planet and star as Jupiter swung by Regulus February 19 and May 5, 2 B.C. *Astronomy*: Roen Kelly

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

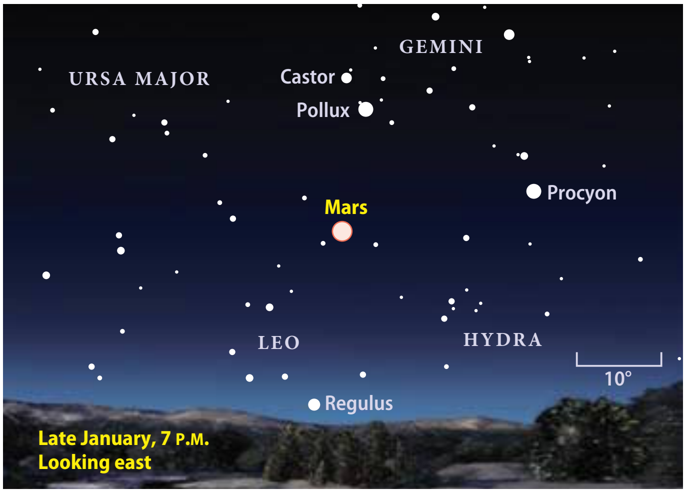
January 2010

Mars shines big and bright



ESA/MPS

The Red Planet looms large this month as it comes close to Earth. A small telescope will reveal dusky surface markings and the icy north polar cap.



Late January, 7 P.M.
Looking east

Mars gleams at opposition January 29. A Full Moon then lies nearby, so the planet stands out more a few days earlier and later. *Astronomy*: Roen Kelly

One of the great pleasures in observing the night sky is viewing the planets through a telescope. At almost any time of the year, either Jupiter or Saturn (or both) will be on display. Add to those the occasional appearances of Mercury and Venus, and there's always something new to see.

Mars ranks as more of a rarity. Once every 26 months or so, the Red Planet makes a grand appearance. That time is now. Mars reaches opposition and peak visibility in January, when it rightfully claims the bulk of our planet-viewing attention.

Mars does have some competition, however. Brilliant Jupiter makes its final stand in the evening sky before twilight swallows it. Shortly before midnight, Saturn joins the scene. And with Saturn high in the south before dawn in late January, Mercury puts on a nice show.

Let's start our tour of the solar system where we normally do, in the western sky shortly after sunset. The first object you'll see is **Jupiter**. The giant planet shines at magnitude –2.1 in the southwest and appears as a beacon against the background stars. It crosses from Capricornus into Aquarius during January's first week.

As the year begins, Jupiter sets nearly 4 hours after the Sun and remains conspicuous even after twilight fades away. But by January's close, the observing window shrinks noticeably. Jupiter then sets during late twilight, less than 2 hours after sunset.

This low altitude means viewing the planet through a telescope will highlight Earth's turbulent atmosphere more than fine features in Jupiter's atmosphere. Unless you have exceptional conditions, don't expect to see more than two dark belts on the planet's 34"-diameter disk.

Although atmospheric features will be difficult to discern, Jupiter's four bright moons will continue to stand out. Look for Io, Europa, Ganymede, and Callisto as

— Continued on page 49

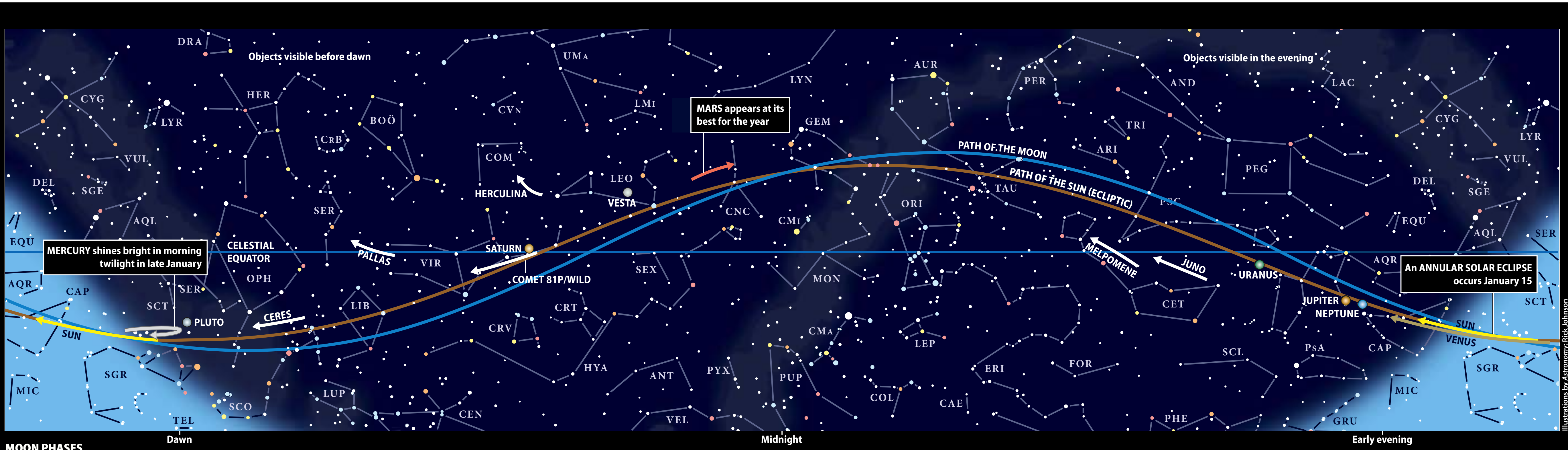
40 **Red Planet delight** 👁 ∞ 🔭
49 **Meteor watch** 👁
49 **Rising Moon** 🔭
50 **When to view the planets** 👁 ∞ 🔭
50 **Galilean moons on parade** 🔭
50 **Comet search** 🔭
51 **Locating asteroids** ∞ 🔭
51 **The Moon eclipses the Sun** 👁 ∞ 🔭

👁 **Visible to the naked eye**
∞ **Visible with binoculars**
🔭 **Visible with a telescope**

Planets in January 2010

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine


DRA
Objects visible before dawn
UMA
CYG
LYR
HER
CVN
CRB
BOÖ
LMI
COM
VUL
DEL
SGE
HERCULINA
LEO
VESTA
SER
AQL
EQU
CELESTIAL
EQUATOR
PALLAS
VIR
SATURN
COMET 81P/WILD
OPH
AQR
CAP
SER
SCT
PLUTO
CERES
LIB
SUN
CRV
CRT
SGR
MIC
TEL
SCO
LUP
CEN
HYA
ANT
PYX
VEL
SEX
LYN
GEM
CNC
CMI
MON
CMA
PUP
AUR
PER
ORI
TAU
LEP
COL
CAE
ERI
FOR
PATH OF THE MOON
PATH OF THE SUN (ECLIPTIC)
TRI
ARI
AND
LAC
PEG
PSC
MELPOMENE
JUNO
URANUS
CET
JUPITER
NEPTUNE
SCL
PSA
PHE
GRU
CAP
MIC
SGR
SUN
VENUS
AQR
EQU
AQL
SER
SCT
CYG
LYR
VUL
DEL
SGE
Objects visible in the evening
Dawn
Midnight
Early evening

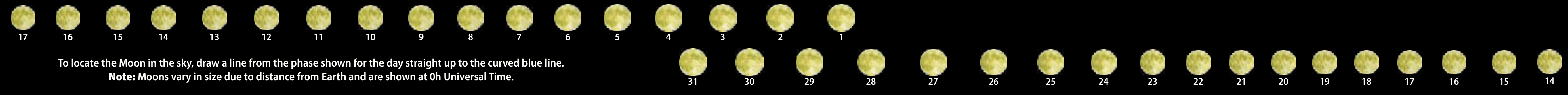
MERCURY shines bright in morning twilight in late January

MARS appears at its best for the year

An ANNULAR SOLAR ECLIPSE occurs January 15

Illustrations by *Astronomy:* Rick Johnson

MOON PHASES


17
16
15
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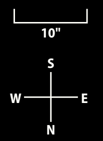
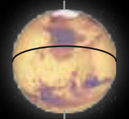
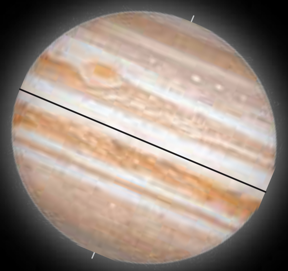
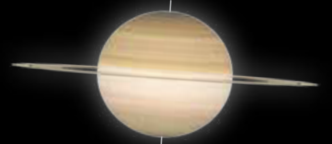
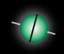
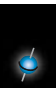
19
18
17
16
15
14

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

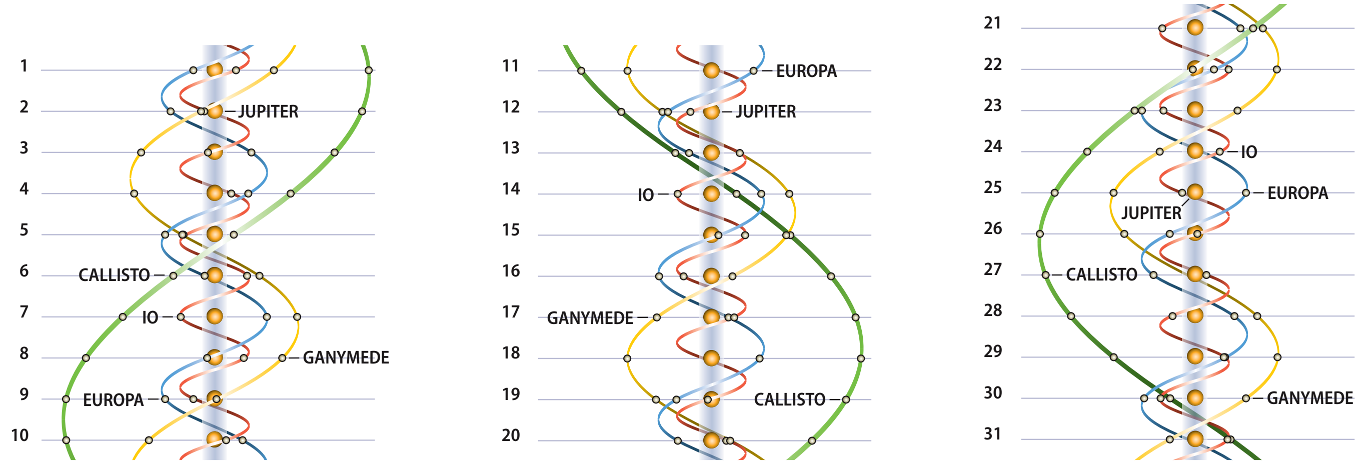


PLANETS	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	January 31	January 31	January 15	January 15	January 15	January 15	January 15	January 15	January 15
Magnitude	–0.2	–3.9	–1.1	9.0	–2.1	0.8	5.9	8.0	14.1
Angular size	6.3"	9.8"	13.7"	0.4"	34.1"	18.3"	3.4"	2.2"	0.1"
Illumination	69%	100%	99%	98%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.066	1.705	0.682	3.326	5.778	9.097	20.589	30.869	32.683
Distance (AU) from Sun	0.442	0.728	1.639	2.717	5.000	9.479	20.097	30.024	31.770
Right ascension (2000.0)	19h10.9m	21h13.2m	9h16.1m	16h35.5m	22h06.5m	12h20.3m	23h36.8m	21h49.3m	18h15.4m
Declination (2000.0)	–21°58'	–17°28'	20°20'	–18°15'	–12°38'	0°22'	–3°18'	–13°37'	–18°18'

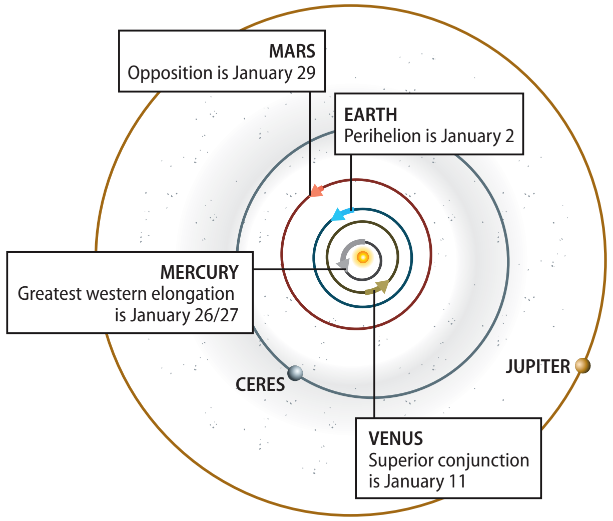
Jupiter's moons

Dots display positions of Galilean satellites at 9 P.M. EST on the date shown.
South is at the top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during January.

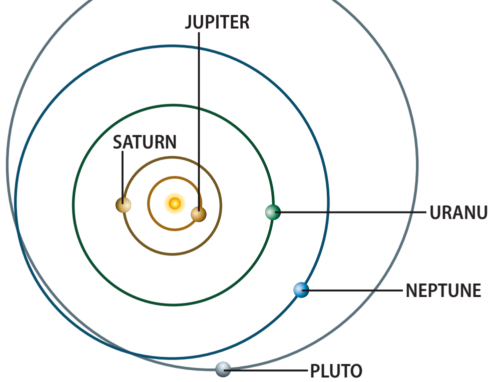

CERES
JUPITER

MARS
Opposition is January 29

EARTH
Perihelion is January 2

MERCURY
Greatest western elongation is January 26/27

VENUS
Superior conjunction is January 11


JUPITER
SATURN
URANUS
NEPTUNE
PLUTO

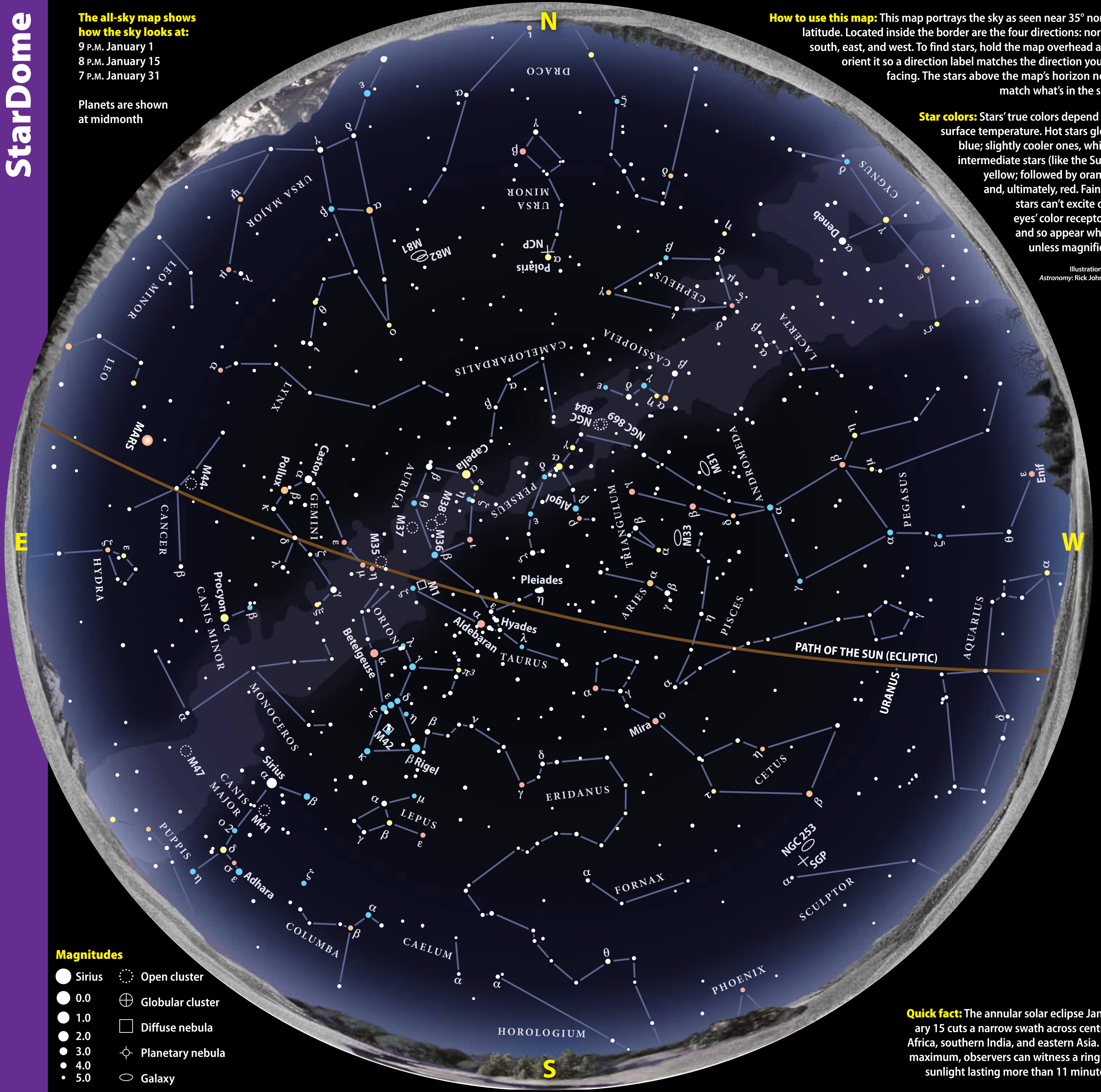
StarDome

The all-sky map shows how the sky looks at:
9 P.M. January 1
8 P.M. January 15
7 P.M. January 31

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.


N
S
E
W
DRACO
URSA MINOR
URSA MAJOR
NCP
Polaris
M81
M82
CYGNUS
Deneb
CEPHEUS
LACERTA
CASSIOPEIA
CAMELOPARDALIS
LEO MINOR
LEO
LYNX
MARS
M44
CANCER
Pollux
Castor
GEMINI
AURIGA
Capella
M38
M37
M36
M35
PERSEUS
Algol
NGC 869
NGC 884
TRIANGULUM
M33
ANDROMEDA
M31
PEGASUS
Enif
PISCES
ARIES
Pleiades
Hyades
M1
TAURUS
Aldebaran
ORION
Betelgeuse
M42
Rigel
HYDRA
Procyon
CANIS MINOR
MONOCEROS
Sirius
CANIS MAJOR
M47
M41
Adhara
PUPPIS
COLUMBA
LEPUS
CAELUM
ERIDANUS
FORNAX
Mira
CETUS
URANUS
AQUARIUS
NGC 253
SGP
SCULPTOR
PHOENIX
HOROLOGIUM
PATH OF THE SUN (ECLIPTIC)
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

Illustrations by *Astronomy*: Rick Johnson

Quick fact: The annular solar eclipse January 15 cuts a narrow swath across central Africa, southern India, and eastern Asia. At maximum, observers can witness a ring of sunlight lasting more than 11 minutes.

January 2010

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

Calendar of events

1 The Moon is at perigee (222,875 miles from Earth), 3:33 P.M. EST

2 Earth is at perihelion (91.4 million miles from the Sun), 7 P.M. EST

3 The Moon passes 7° south of Mars, 7 A.M. EST

Quadrantid meteor shower peaks

4 Mercury is in inferior conjunction, 2 P.M. EST

6 The Moon passes 8° south of Saturn, 2 P.M. EST

7 Last Quarter Moon occurs at 5:39 A.M. EST

Asteroid Vesta is stationary, 4 P.M. EST

11 The Moon passes 1.1° north of Antares, 8 A.M. EST

Venus is in superior conjunction, 4 P.M. EST

13 The Moon passes 5° south of Mercury, 11 A.M. EST

14 Saturn is stationary, 2 P.M. EST

15 New Moon occurs at 2:11 A.M. EST; annular solar eclipse

Mercury is stationary, 11 A.M. EST

16 The Moon is at apogee (252,547 miles from Earth), 8:40 P.M. EST

17 The Moon passes 4° north of Neptune, 6 P.M. EST

18 The Moon passes 5° north of Jupiter, 5 A.M. EST

20 The Moon passes 6° north of Uranus, 6 A.M. EST

23 First Quarter Moon occurs at 5:53 A.M. EST

26 Mercury is at greatest western elongation (25°), midnight EST

27 Mars comes closest to Earth (61.7 million miles away), 2 P.M. EST

29 Mars is at opposition, 3 P.M. EST

Special observing date

29 Mars shines brighter at opposition (magnitude –1.3) than at any time in the past 2 years.

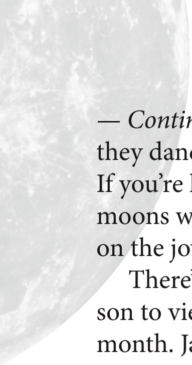
30 Full Moon occurs at 1:18 A.M. EST

The Moon passes 7° south of Mars, 3 A.M. EST

The Moon is at perigee (221,577 miles from Earth), 4:05 A.M. EST

See tonight's sky in Astronomy.com's STARDOME

Astronomy magazine



— Continued from page 40

they dance around the planet. If you're lucky, one of the moons will cast a shadow on the jovian cloud tops.

There's another good reason to view the moons this month. January marks the 400th anniversary of when Galileo discovered these four satellites. The great Italian scientist spotted Io, Europa, and Callisto January 7, 1610, and Ganymede 6 days later. Even the smallest modern telescope outperforms Galileo's instrument, so the moons show up as bright pinpoints of light arrayed on either side of Jupiter.

Distant **Neptune** lies just 2° to Jupiter's lower right as January begins. Look for it through a telescope during 2010's first week when it still appears against a dark background. The 8th-magnitude planet disappears into the twilight glow around mid-month. Count yourself lucky if you simply spot Neptune's blue-gray dot.

Uranus fares better. It lies one constellation east of Jupiter, sliding from Aquarius into Pisces in mid-January. Uranus appears to Jupiter's upper left and sets some 2 hours after the brighter planet.

Uranus glows at magnitude 5.9 and shows up easily through 7x50 binoculars. You'll need a small telescope to see the planet's blue-green disk, which spans 3.4". Look for Uranus below Pisces' Circlet asterism, some 5° south of the 5th-magnitude star Lambda (λ) Piscium.

By late January, **Mars** shines conspicuously in the east as darkness falls. It passes from Leo the Lion into Cancer the Crab during January's second week, although you don't need any background stars to identify the planet. Mars appears distinctly reddish and shines brighter than any other point of light in the sky except for Sirius (which lies well to Mars' right) and

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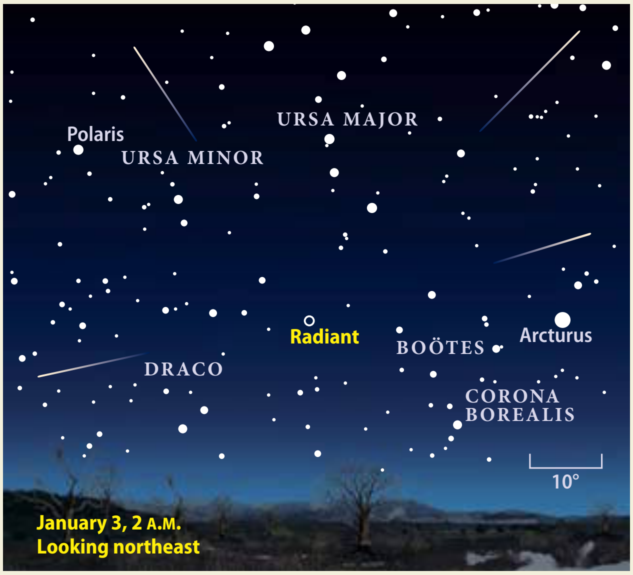
Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc. in Nashua, New Hampshire. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

Meteor watch



The Quadrantid meteor shower peaks **January 3, when you can expect to see a few dozen meteors per hour.** *Astronomy*: Roen Kelly

Hot flashes hit a cold winter's night

January's lone major meteor shower rises to a sharp peak January 3. The Quadrantid shower can produce up to 120 meteors per hour under excellent conditions. Unfortunately, a bright Moon interferes with the shower this year, cutting the observed number significantly. Still, the Quadrantids produce a high percentage of bright meteors, so the shower will be worth viewing.

The Quadrantids' radiant lies in northern Boötes, which climbs high in the northeast before dawn. (The shower gets its name from a defunct constellation, Quadrans Muralis.) With Mars lying near the Moon and Saturn high in the south that morning, the sky will have plenty of observing treats.

Rising **Moon**

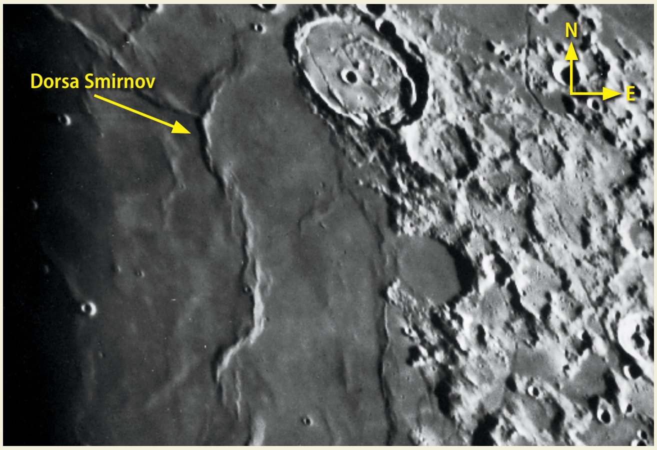
Snaking across the Sea of Serenity

One of the most striking sights on Mare Serenitatis (the Sea of Serenity) is the long complex of wrinkle ridges known as Dorsa Smirnov (also called the Serpentine Ridge). But the timing has to be just right. Shortly after the Sun rises over this region, the modestly lifted terrain casts long shadows across Serenity's hardened lava plains. The paired dark and sunlit faces will appear striking January 20 but will disappear under a higher Sun just a day later.

Look northeast of Dorsa Smirnov, and you can't miss the fantastic crater Posidonius. It's a joy getting lost in the wonderful detail visible through a small telescope. For starters, there are small craters, bumps, rilles, and a second wall.

Much farther south, the trio of Theophilus, Cyrillus, and Catharina appear just as striking. The three craters are nicely ordered by age from north to south, with Catharina being the most time-worn and battered compared with the young and sharp-featured Theophilus.

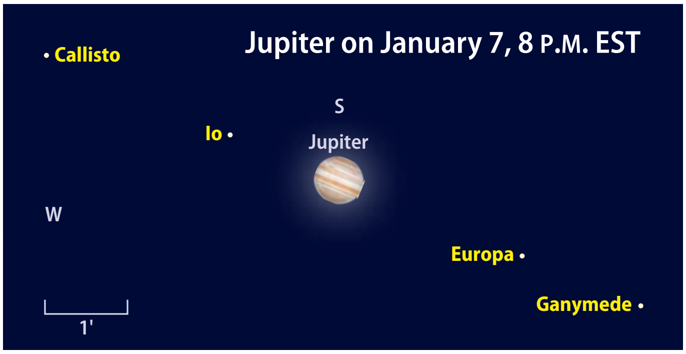
A special event occurs along a path from Cape Cod, through southern Vermont, to west of Ottawa near sunrise January 11. Observers there can watch the Moon graze the 1st-magnitude star Antares. During most grazing occultations, a star blinks off and on as each lunar mountain covers it. But the red supergiant Antares is so big that it often fades only partially. For details on this occultation, visit www.lunar-occultations.com/iota. Observers outside Alaska won't witness another lunar occultation of Antares until 2023.



A series of wrinkle ridges **known as Dorsa Smirnov snakes across the dark lava plains of Mare Serenitatis.** *Consolidated Lunar Atlas*/UA/LPL

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Jupiter (southwest)	Mars (southeast)	Mercury (southeast)
Uranus (southwest)	Saturn (east)	Mars (west)
		Saturn (southwest)



Jupiter's four Galilean moons always put on a show, but the view will be particularly satisfying January 7 — the 400th anniversary of when Galileo discovered three of them. *Astronomy*: Roen Kelly

Jupiter (which sets in the west not long after Mars appears). Mars brightens by more than 50 percent this month, climbing from magnitude –0.8 January 1 to magnitude –1.3 at opposition January 29.

Although Mars appears biggest through a telescope around opposition, it remains quite small. Its apparent size grows from 12.7" January 1 to its peak of 14.1". Although a nearly Full Moon passes Mars both January 2 and 29, you don't need a dark sky to observe the planet.

For the best views of the martian disk, wait until the planet climbs high in the south around midnight. Its greater altitude then means you'll view it through less of Earth's turbulent, image-distorting atmosphere.

Mars rotates on its axis once every 24 hours and 37 minutes. This extra half-hour above and beyond Earth's rotation means that if you view Mars at the same time each night, the surface will appear to rotate backward 9° from one night to the next. This shift accumulates during the course of a month to let you view most of the martian surface. Of course, the planet rotates almost 15° each hour, so observing all night presents most of the surface to you as well. Just remember to bundle up against the cold.

Mars' white north polar cap continues to dominate the disk because the planet's north pole now tilts toward Earth. Features closer to the equator appear best when they lie near the disk's center. The following list summarizes when some prominent features lie near Mars' central meridian at midnight EST (9 P.M. PST): on January 1, Sabaeus Sinus, Mare Acidalium, and Chryse Planitia; January 7, Sabaeus Sinus, Syrtis Major, and Hellas; January 14, Syrtis Major and Hellas; January 21, Mare Cimmerium, Mare Sirenum, Elysium, and Amazonis; January 28, Solis Lacus, Tharsis, and Olympus Mons (which is visible only in large backyard telescopes).

By the time Mars reaches its highest position in the south, **Saturn** already shines brightly in the southeast. Saturn now lies among the stars of Virgo the Maiden. At magnitude 0.8, it shines slightly brighter than that constellation's brightest star, Spica. Saturn will brighten a bit more by the time it reaches opposition in March.

The ringed planet parks 1° north of the 4th-magnitude star Eta (η) Virginis all month. Saturn barely moves relative to Eta because the planet's eastward motion comes to a halt in mid-January. Saturn then starts to move westward, but picks up speed slowly.

Saturn's disk spans 18" in mid-January, and the rings extend more than twice this width. The rings tilt 5° to our line of sight, their widest since 2008. They will narrow somewhat by summer, but widen even more by the end of 2010.

Any telescope will show you 8th-magnitude Titan, Saturn's brightest moon. It lies close to the planet's disk the mornings of January 2, 10, 18, and 26.

Several fainter moons provide more of a challenge. Tethys, Dione, and Rhea glow at 10th magnitude and show

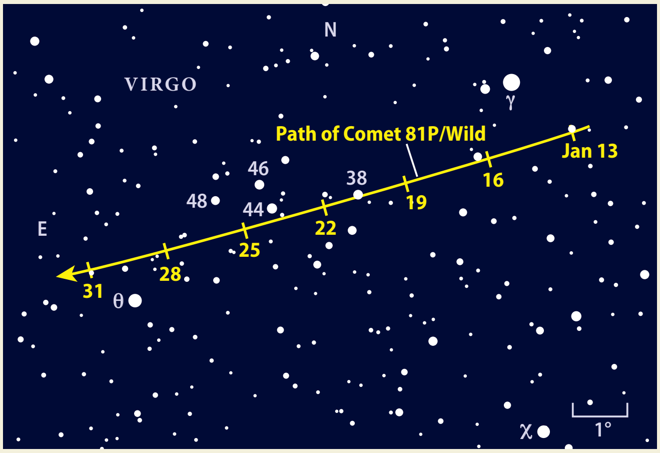
Comet search

Have a Wild time these January nights

Before closing an observing session with Saturn, check out the form of Comet 81P/Wild. This well-behaved periodic comet spends the first week of January just 1° south of the magnificent ringed world before heading farther east. Glowing at 10th magnitude, Wild is a bit fainter than the Messier galaxies that populate its host constellation Virgo, so you'll need to be away from city lights to get a decent look.

Because Wild's orbit lies close to the plane of our solar system, we see it almost edge-on. Comets typically display diffuse fan-shaped dust tails. But our perspective this month turns Wild's dust tail into a bright, almost sharp streak. All the sunlight that scatters off dust particles in the fan-shaped tail adds up when compressed into a thin slice of sky. The comet's coma should appear round and condensed.

Last August, scientists announced that they had found the amino acid glycine in material ejected by Comet 81P/Wild. (NASA's Stardust spacecraft returned these comet samples to Earth in 2006.) The discovery marks the first detection in a comet of an amino acid, one of life's fundamental building blocks.



Comet 81P/Wild glows at 10th magnitude among the stars of Virgo. It passes 1° south of Saturn during January's first week, but glows brighter toward month's end. *Astronomy*: Roen Kelly

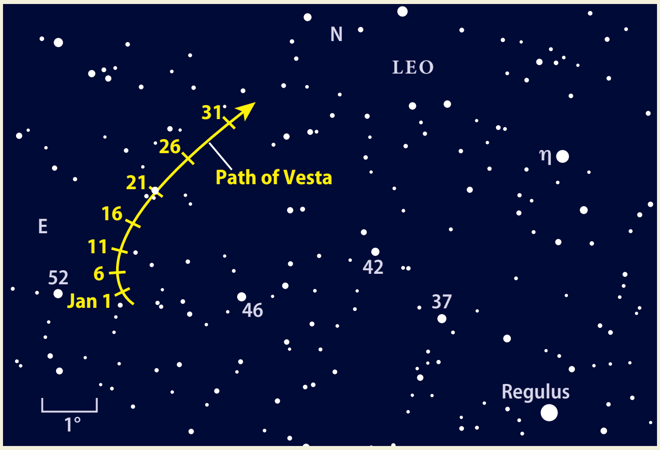
Locating **asteroids**

Vesta has the heart of a lion

You don't even need a telescope to view this month's asteroid highlight. You can track 4 Vesta easily through binoculars. Simply walk outside, dark adapt for 5 minutes or so, and you'll be ready to locate this large space rock. Try this every few nights, and you'll notice Vesta shifting slightly relative to the background stars of Leo the Lion.

This constellation rises in the east during late evening. Vesta lies a short hop from blue-white Regulus, Leo's 1st-magnitude luminary and the star at the heart of the Lion. To find Vesta, first locate the guide stars 46 and 52 Leonis. The only other object in this region brighter than 7th-magnitude Vesta is a lone 6.6-magnitude field star.

On the night of January 21/22, that lone star forms a tight pair with the 320-mile-wide asteroid. Only 3' separate the two at closest approach. Swing your telescope to the duo, and look at their colors. Vesta glows by reflecting sunlight, so it appears a pale yellow. The field star is only one spectral class different from the Sun, so it should shine with a similar hue. Can you detect any difference?



Vesta treks across Leo, not far from 1st-magnitude Regulus. The asteroid glows at 7th magnitude throughout January. *Astronomy*: Roen Kelly

up easily in 6-inch telescopes. All three orbit closer to Saturn than Titan does. Iapetus, on the other hand, lies much farther from the planet and takes 80 days to complete an orbit.

But that's not what makes Iapetus special. This moon has one hemisphere as dark as coal and the other as bright as freshly fallen snow. As the moon orbits Saturn, it changes brightness dramatically. It appears brightest when farthest west of Saturn and dimmest when farthest east.

Iapetus reaches greatest eastern elongation January 10, when it glows at 12th magnitude and will be difficult to spot through an 8-inch scope. As January progresses, Iapetus heads westward. It passes 1.5' due south of Saturn the morning of January 29 — a good time to spot this 892-mile-wide moon.

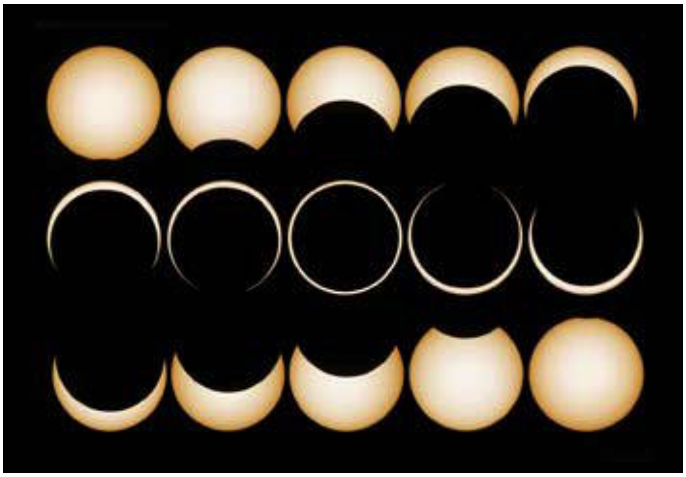
As twilight starts to paint the sky in the second half of January, try to spot **Mercury**. The innermost planet passes between the Sun and Earth (a configuration known as inferior conjunction) January 4 and then leaps into the morning sky. You may spot it as early as January 13, when it appears 7° high in the southeast 30 minutes before sunrise. If you have exceptionally clear skies and a flat horizon, look for a thin crescent Moon 5° south of Mercury.

Mercury shines at magnitude 0.8 that morning, but it brightens rapidly. It climbs to magnitude –0.2 by January 26/27, when it reaches greatest elongation. The planet then lies 25° west of the Sun and appears 9° above the horizon 30 minutes before sunrise.

A telescope reveals rapid changes in Mercury's appearance. On January 13, the planet's disk spans 9" and appears 23 percent lit. Its phase waxes to half-lit January 21 and to 63 percent illumination by the 27th. On that morning, Mercury measures 7" across.

The sky's brightest planet remains out of sight all month. **Venus** reaches superior conjunction January 11, when it lies on the far side of the Sun from Earth.

At 7 P.M. EST January 2, **Earth** reaches perihelion — the closest point to the Sun during its yearly orbit. At perihelion, Earth lies 91.4 million miles from the Sun, some 3.1 million miles closer than at its farthest point in early July.



A ring of sunlight (center) remains visible at the peak of an annular solar eclipse. This sequence shows the October 2005 eclipse from start (top left) to finish (bottom right). Observers in parts of Africa and Asia will see such an eclipse January 15. David Tyler and Damian Peach

Earth's proximity to the Sun this month causes our star to appear slightly larger in the sky. This contributes to one of January's more impressive events: an **annular solar eclipse**. On the 15th, the Moon passes directly between the Sun and Earth. But the relatively small Moon on that date fails to cover the big Sun, leaving a ring of sunlight visible at maximum.

Observers will see this annular eclipse along a narrow path that begins in central Africa and then treks across the Indian Ocean, through southern India, Sri Lanka, Burma, and, ultimately, China. Viewers in much of Africa, eastern Europe, and Asia will witness a partial eclipse. Be sure to use a safe solar filter to directly view the eclipsed Sun.

On the morning of January 1, skywatchers in Asia and Australia will see a **partial lunar eclipse**. At maximum, 8 percent of the Moon lies in Earth's umbral shadow. From Africa, Europe, and the northeastern and northwestern corners of North America, this eclipse occurs on the evening of December 31.

How do planetary

Over the past decade, astronomers have cracked the code of planetary nebula shapes. Now we know why these stellar coffins appear in such a variety of intricate styles. **by David J. Eicher**

Distinctive with its butterfly shape, the Little Dumbbell Nebula (M76) in Perseus presents a moderate challenge for small-scope users.

Adam Block/NOAO/AURA/NSF

A classic round planetary, the Owl Nebula (M97) in Ursa Major has two dark areas that appear like "eyes" in backyard telescopes.

Gary White and Verlenne Monroe/Adam Block/NOAO/AURA/NSF

Planetary nebulae are the last gasps of dying stars. These clouds of ionized gas glowing by fluorescence — powered by the hot ember of the stellar corpse within — fascinate backyard observers because many are bright and relatively easy to see in small telescopes, even from moderately light-polluted areas. Their short life spans, only about 50,000 years out of the billions of a star's life, offer an intimate glimpse into stellar evolution. They hold the keys to the story of how our Sun will end its days.

Nearly all stars become planetary nebulae. And yet astronomers have only recently unraveled the details of how such objects form and evolve.

Getting the shape of things

One key area of planetary nebula research has really taken off. Astronomers have resolved the mystery of planetary nebula shapes. That's a first step in understanding other more complex mysteries. Throughout the history of exploring the world and the cosmos, scientists first catalog objects, classify them, and then move on to deeper understanding.

The cataloging of planetary nebulae, at least within our Milky Way Galaxy, has largely been done. Astronomers now know of more than 3,000 planetaries in the galaxy, some 500 of which are bright enough to view or image with backyard

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David J. Eicher *is the editor of* Astronomy. *He has observed planetary nebulae since 1976.*

nebulae form?

Adam Block/NOAO/AURA/NSF

Small and bright, NGC 1535 in Eridanus is a classic round planetary and has strange interactions visible within its bright inner disk.

The Ring Nebula in Lyra (M57) is the archetypal planetary nebula, the most observed object of its type. Adam Block/NOAO/AURA/NSF

telescopes. (Additionally, quite a few planetary nebulae have been cataloged in nearby galaxies.) Over the past 20 years or so, a group of astronomers has focused on planetary nebula research. Bruce Balick of the University of Washington, Adam Frank of the University of Rochester, Mario Livio of the Space Telescope Science Institute, and others have nailed down the process by which planetary nebulae form.

In short, a planetary nebula develops when a star of similar mass to the Sun exhausts its nuclear fuel and begins an old-age phase. After the normal sequence of events that takes a star like this through a detour as a red giant, the star's core becomes an Earth-sized lump of carbon. It begins fusion, which occurs in fits and starts, ejecting shells or bullets of gas into space surrounding the star. (For a detailed analysis of how a planetary nebula forms, see "How the Sun will die" by Bruce Balick in the December 2008 *Astronomy*.)

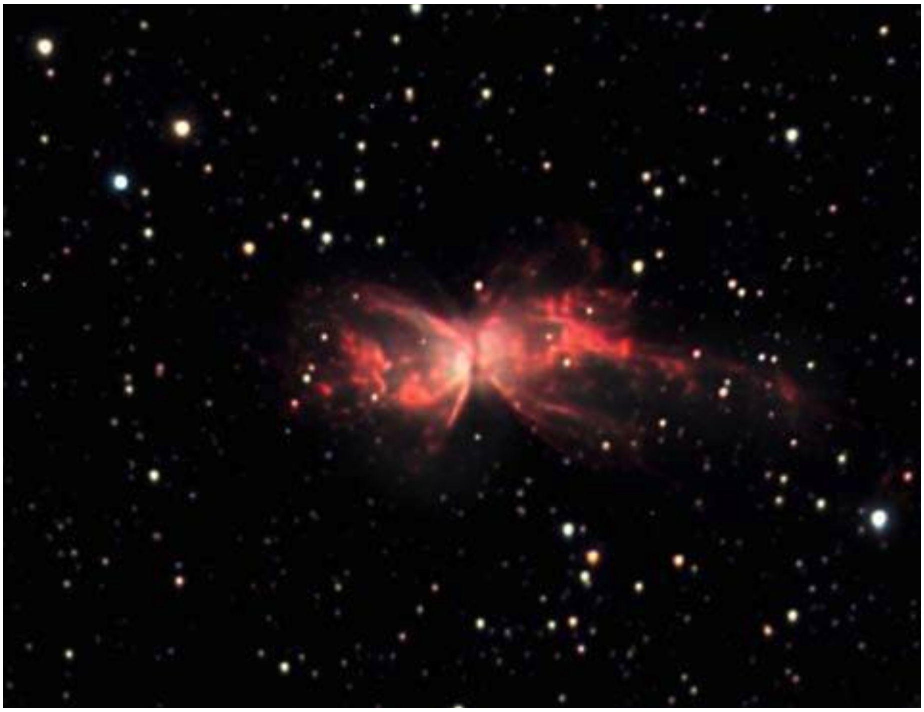
The shells of gas, expanding at high velocities into the surrounding space, form a beautiful show as they glow by ionization and run into the surrounding interstellar medium, creating a large number of intricate shapes and patterns. How can we make sense of these objects in some coherent, organized way?

Planetary nebulae: The early days

For some 225 years, the question of what the heck planetary nebulae are and how these things form remained murky. To underscore the confusion over these objects, they started out with a funny name; planetary nebulae have nothing to do with planets.

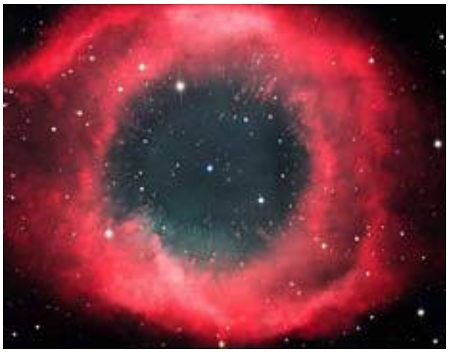
The name arose during the 18th century when many observers who stumbled upon these objects believed their disklike structures, some of which appeared strongly blue-green, resembled planets as seen with their telescopes. The famous French comet-hunter Charles Messier observed and cataloged the first planetary nebula in 1764 when he spotted the Dumbbell Nebula in Vulpecula and recorded it as Object 27 in his famous list of things to avoid.

Other discoveries followed, although they were slow relative to other deep-sky



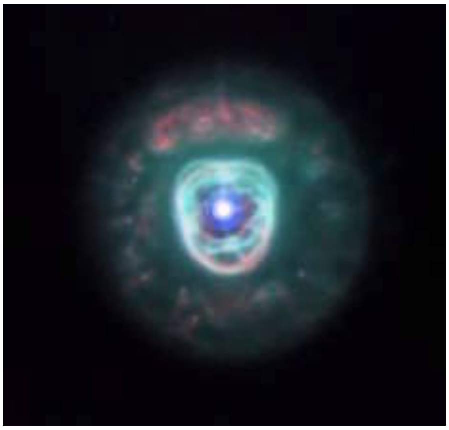
Adam Block/NOAO/AURA/NSF

Highly flattened, the late-stage butterfly-shaped object called the Bug Nebula (NGC 6302) in Scorpius presents an extreme planetary nebula. Perhaps it ought to be called the "Squashed Bug."

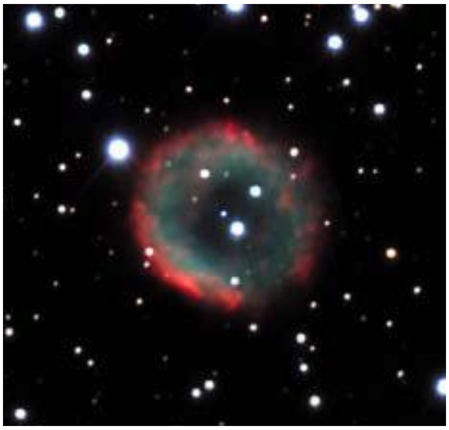


Adam Block/NOAO/AURA/NSF

The largest planetary nebula in the sky, the Helix Nebula (NGC 7293) offers a challenge to observers due to its low surface-brightness.



A famous standout in the winter sky, the Eskimo Nebula (NGC 2392) in Gemini resembles a face surrounded by a parka hood. This round nebula is sometimes called the Clown Face Nebula. Peter and Suzie Erickson/Adam Block/NOAO/AURA/NSF



Floating amid the stars of M46, the late-stage round planetary NGC 2438 in Puppis is an elderly ring, a strange hoop of gas surrounding the bright central star. Nicole Bies and Esidro Hernandez/Adam Block/NOAO/AURA/NSF

objects mostly because planetary nebulae are small compared with clusters, emission nebulae, and galaxies. William Herschel made the biggest gains in finding planetaries, even if he didn't know what they were, and applied the name to his class of small, round nebulae that reminded him of Uranus.

The British amateur astronomer William Huggins pushed the study of nebulae forward in the mid-19th century by turning a spectroscope toward many nebulae. In 1864, as the Civil War raged on in America, Huggins systematically studied stars and nebulae and found that they resemble the Sun in gaseous structure. He carefully examined NGC 6543 in Draco and found "a single bright line only!" He remarked in his notes that "the riddle of the nebulae was solved. The answer, which had come to us in the light itself, read: Not an aggregation of stars, but a luminous gas."

By the 20th century, with the dawn of modern astrophysics, the study of planetary nebulae catapulted forward. Yet in 1918, fewer than 100 planetaries were known, and astronomers didn't yet understand the nature of galaxies. Few professional astronomers specialized in studying planetary nebulae, so a generalized list of the objects did not exist until recently. Planetaries lay scattered throughout various catalogs.

In 1967, this deficiency evaporated when astronomers Lubos Perek and Lubos Kohoutek (of Comet Kohoutek fame) published their *Catalogue of Galactic Planetary Nebulae*, which contains 1,036 nebulae. This act marked the first step in modern planetary nebula research and remains the standard reference catalog on planetary nebulae, often referred to simply as "P&K."

Just how are these things shaped, anyway?

Research went on with the normal sorts of discovery, analysis, publication of papers, estimates of ages, sizes, compositions, and so on. But no one until the 1990s, with the aid of the Hubble Space Telescope, began to crack the mystery of how planetary nebulae are shaped.

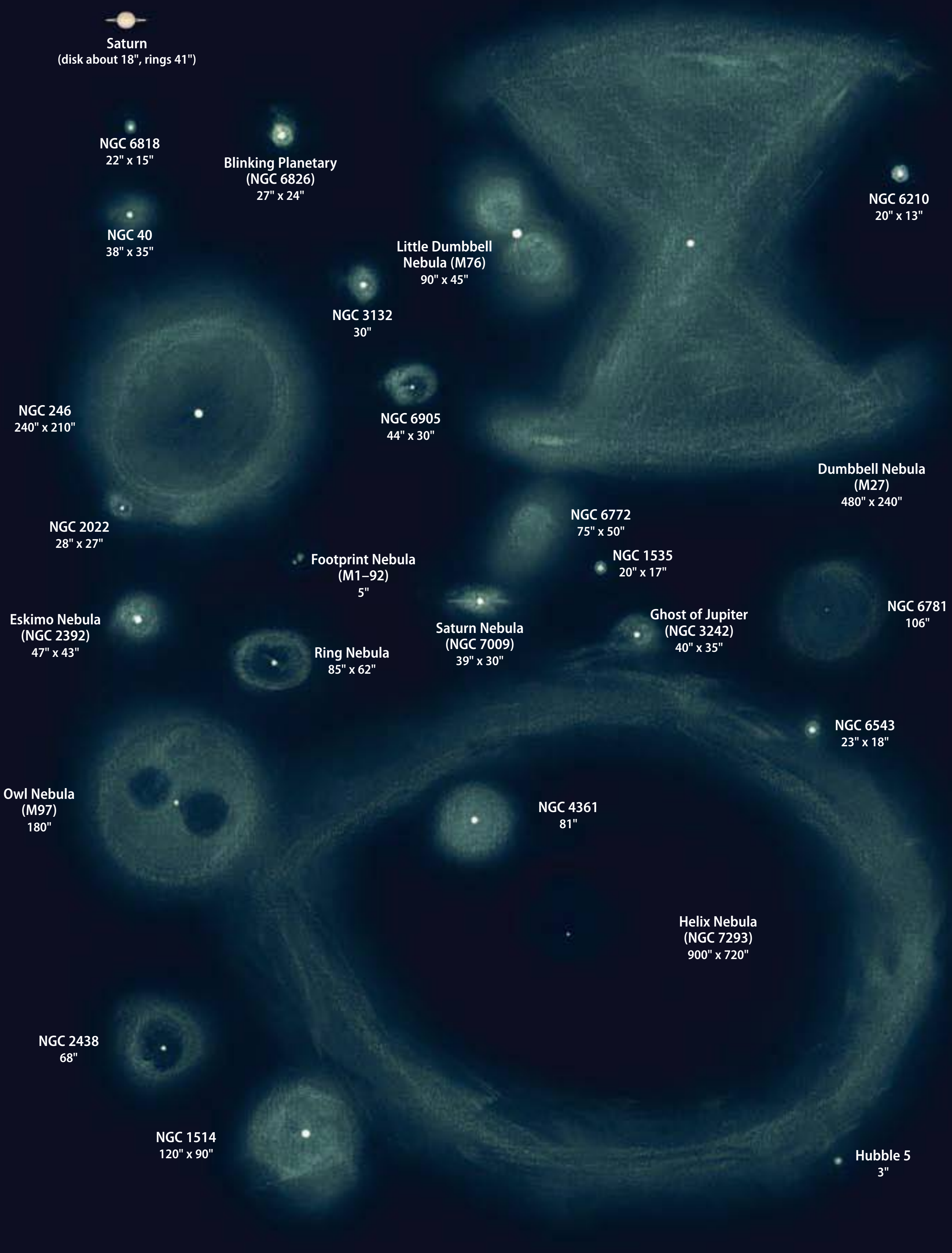
Enter the Balick gang. The conundrum was that planetary nebulae as we see them seem to have a huge array of shapes, sizes, brightnesses, and so on, such that making a coherent story out of their physical nature was daunting.

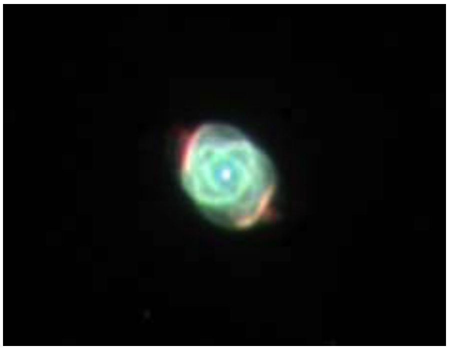
A similar discovery process was also going on and which is mostly solved now. On a parallel track, it studied the apparently very different forms of active galaxies that seemed to be harboring black holes. (More on that in another issue.)

The solution for planetaries came down to classifying the basic structural types in the planetaries and then understanding the complexities thrust upon them because we are viewing the nebulae

How we see 25 bright planetary nebulae

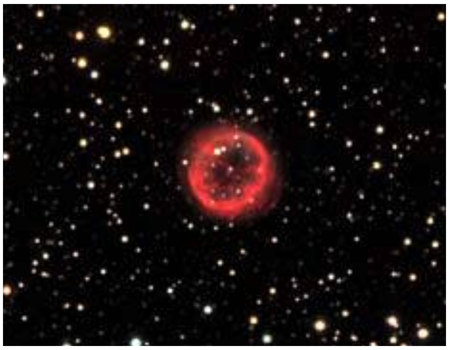
In backyard telescopes, planetary nebulae take on a wide variety of shapes and sizes because some are close and some distant, some round and some elongated, and some with disks essentially “face-on,” others angled sharply to our line of sight. This diagram depicts 25 planetary nebulae as they appear in moderate-sized backyard scopes, all shown to scale, and with Saturn added for perspective. *Astronomy*: David J. Eicher and Roen Kelly


Saturn
(disk about 18", rings 41")
NGC 6818
22" x 15"
Blinking Planetary
(NGC 6826)
27" x 24"
NGC 6210
20" x 13"
NGC 40
38" x 35"
Little Dumbbell
Nebula (M76)
90" x 45"
NGC 3132
30"
NGC 246
240" x 210"
NGC 6905
44" x 30"
Dumbbell Nebula
(M27)
480" x 240"
NGC 6772
75" x 50"
NGC 2022
28" x 27"
Footprint Nebula
(M1–92)
5"
NGC 1535
20" x 17"
Ghost of Jupiter
(NGC 3242)
40" x 35"
NGC 6781
106"
Eskimo Nebula
(NGC 2392)
47" x 43"
Saturn Nebula
(NGC 7009)
39" x 30"
Ring Nebula
85" x 62"
NGC 6543
23" x 18"
Owl Nebula
(M97)
180"
NGC 4361
81"
Helix Nebula
(NGC 7293)
900" x 720"
NGC 2438
68"
NGC 1514
120" x 90"
Hubble 5
3"



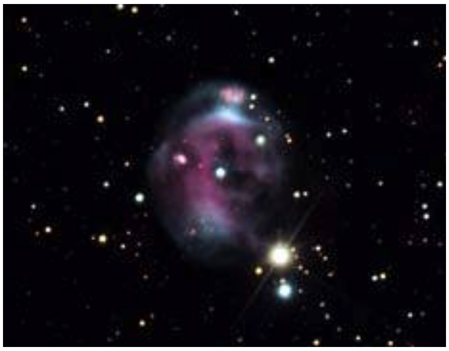
Adam Block/NOAO/AURA/NSF

A mildly elliptical nebula, NGC 6543 in Draco has such a high surface-brightness that it's easy to see from suburban locations, accented by its neon-aqua color.



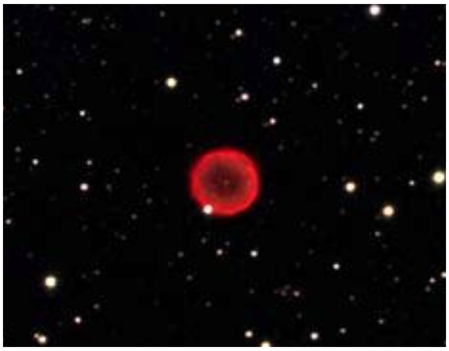
Adam Block/NOAO/AURA/NSF

Ghostly and encased by the Cygnus Milky Way, NGC 6894 presents a round ring to viewers armed with small telescopes.



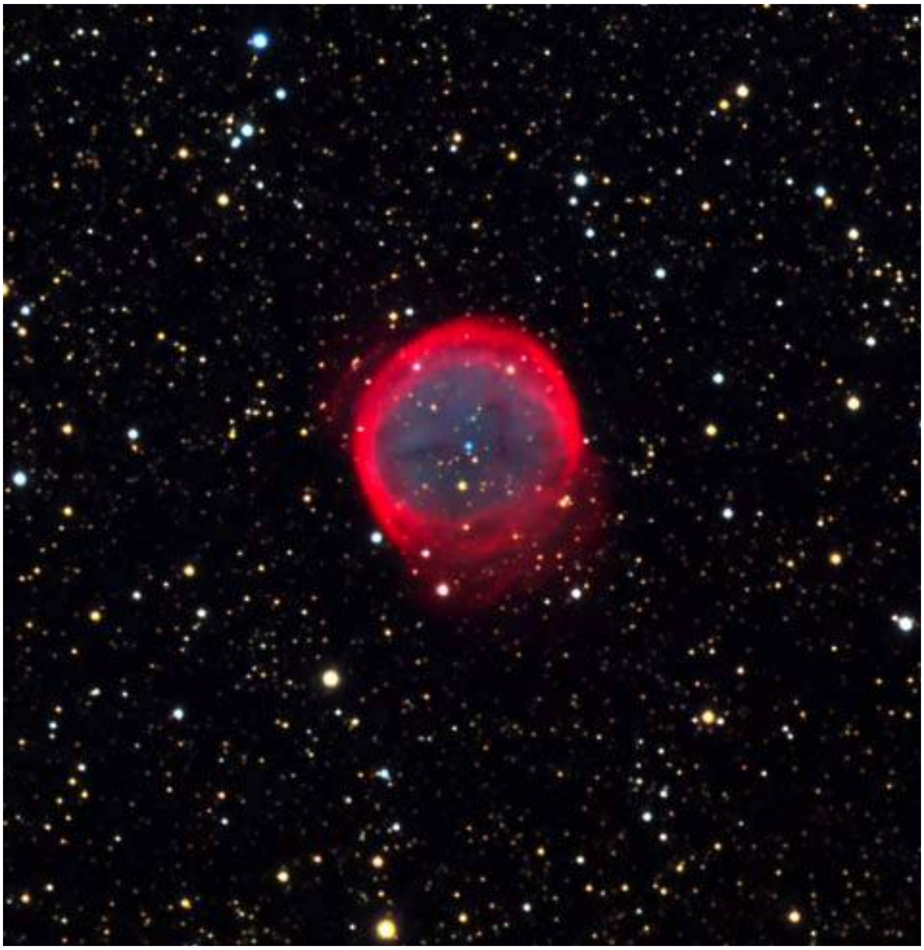
Donn and Aaron Starkey/Adam Block/NOAO/AURA/NSF

A visual train wreck, NGC 7008 in Cygnus presents a flattened ellipse with distorted internal structure amid a bright starfield. It's a definite must for summer observers.



John Pierce/Adam Block/NOAO/AURA/NSF

A classic middle-stage round planetary nebula, PK 40–0.1 in Aquila presents a challenge to visual observers due to its faintness.



Adam Block/NOAO/AURA/NSF

A classic round nebula set in a beautiful starfield, Aquila's NGC 6781 is one of the prettiest objects in the summer sky. Rarely observed, it is overshadowed by the nearby Dumbbell Nebula.

from an infinitive set of geometries as we see them in the sky.

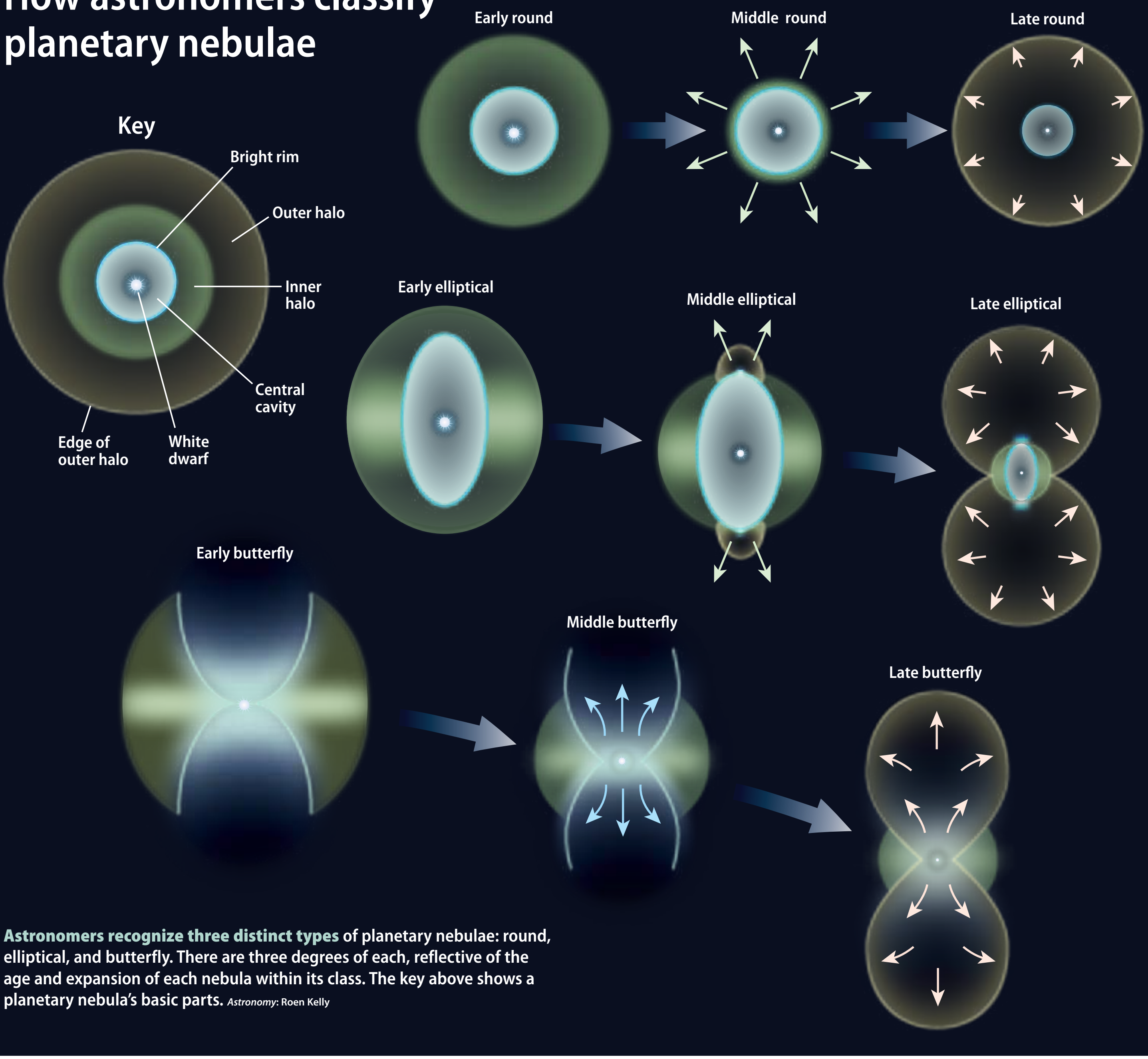
Balick and collaborators proposed that, unlike the myriad varieties we see, just three main classes of planetaries exist: round, elliptical, and butterfly shapes. Within each of these classes, degrees exist based on the nebula's age so that early, middle, and late types look different from one another. Aside from this matrix of nine possible classes, all the further variations in planetaries exist because the nebulae tilt at different angles to our line of sight.

Once this solution sprang forth, just in the past few years, the picture of planetaries and what they mean became clear. Now astronomers could see that some Sun-like stars die and belch off round spheres of material that form halos of glowing gas, with brighter rings inside them. Others blow off a shell of gas and then the helium flash, a final dying gasp from the star that creates an elongated shot of gas and dust. This shoots out at high speed through the older, slower halo. Still others are constricted by a disk that lies within, tidal forces that focus high-speed gas like a cosmic sprinkler, or magnetic forces that shape a planetary into a highly elongated butterfly shape.

Coming to a sky near you

Scientists now know that these three basic shapes and their variations characterize all the planetaries seen in the sky. On the next night out under the stars, spend time looking carefully at planetaries and see what they have to offer. If you've seen a few deep-sky objects during the summer months, you've probably seen two of the greatest such nebulae, the Ring Nebula (M57) in Lyra and the Dumbbell Nebula (M27) in Vulpecula. Find these objects at low power, and then crank up to examine them at 100x or so to see what details you can. View carefully and look with averted vision, gazing off to one side of the field of view to use your eyes' rods, the faint light detectors.

How astronomers classify planetary nebulae


Key
Bright rim
Outer halo
Inner halo
Central cavity
Edge of outer halo
White dwarf
Early round
Middle round
Late round
Early elliptical
Middle elliptical
Late elliptical
Early butterfly
Middle butterfly
Late butterfly

Astronomers recognize three distinct types of planetary nebulae: round, elliptical, and butterfly. There are three degrees of each, reflective of the age and expansion of each nebula within its class. The key above shows a planetary nebula's basic parts. *Astronomy*: Roen Kelly

You should also veer off the list of really bright planetaries to see some weird and challenging ones. Many such objects are scattered along the winter Milky Way and are visible now in the evening sky.

Try the Little Dumbbell Nebula (M76) in Perseus, a lobed object with a bright bar and faint outer loops of nebulosity representing the first shell of material cast off the star. Observe some small bright planetaries like NGC 1535 in Eridanus. That one displays the progenitor star and a bright, mottled disk with an irregular network of loops positioned within a larger, fainter halo of light. When you see this detail, you're viewing the collision of the second burst of material from the star with the fainter gas from the first burst.

The Eskimo Nebula (NGC 2392) in Gemini also boasts a bright central star that's visible in backyard telescopes surrounded by two shells of glowing gas — one bright inner shell and a fainter outer one. Classic ring-shaped nebulae include NGC 2438 in Puppis, a beautiful object that happens to lie amid the stars of M46.

Dozens of others await you, and I suggest planetaries are among the most fascinating objects to observe from your backyard. Their brightness, visibility from less than perfect skies, and strange array of shapes and sizes will amuse you to no end.

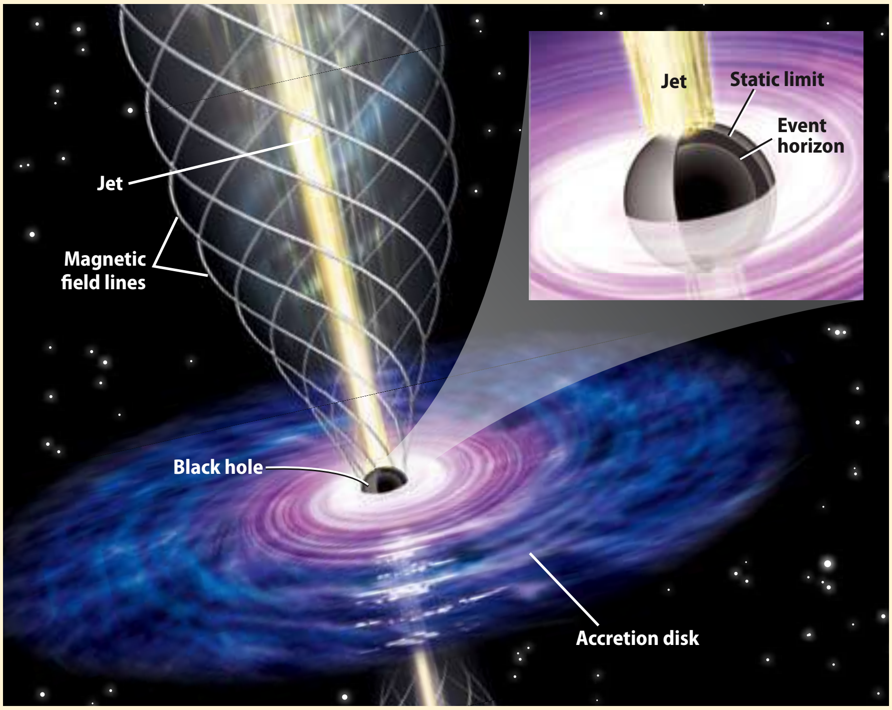
And you can be among the first generation of amateur astronomers that gazes on a planetary nebula and also understands how it formed and why it's shaped the way it is. Who could ask for more than this on a shimmering winter night out under the stars?

See a gallery of more planetary nebula shapes at www.Astronomy.com/toc.

Ask Astro

Astronomy's experts from around the globe answer your cosmic questions.

How jets escape black holes



Astronomy: Roen Kelly

Black hole jets originate from just outside the event horizon, not from the black hole itself. As the black hole pulls matter toward it, the material loses energy. That energy helps power the jets.

Q: I was taught that the gravity of a black hole is so great that nothing, not even light, can escape. But I frequently see pictures of dual energy jets emanating from a black hole. How is this possible? — **Eric Peters,** Anderson, Indiana

A: Gravity is so strong at and within the event horizon of a black hole that nothing, not even light, can escape. Just beyond the event horizon, however, the gravity, while hugely strong, is not overwhelming. That is the site of interesting, energetic, and observable commotion. As matter flows toward the black hole, often in a swirling disk of matter called an accretion disk, energy can be released. **The jets arise from the highly energetic region just beyond the edge of the black hole, not from the black hole itself.**

Within a particular orbit, called the "innermost stable circular orbit" (ISCO), matter tends to plunge toward the event horizon and radiate little, even though it is not yet "over the horizon." The ISCO is a few times larger than the event horizon. At the ISCO, matter orbits at nearly the speed of light, creating heat and generating huge magnetic fields. Observations, basic physics, and sophisticated models show that this combination probably gives rise to the jets observed from both stellar-mass black holes in binary star systems (where the companion star provides the mass to power the process) and supermassive black holes in galactic centers (where galactic gas and stars power the process). — **J. Craig Wheeler,** University of Texas at Austin

TIGHTENING THE BELT

Q: Why hasn't the asteroid belt formed a planet? — **James Neely,** Gastonia, North Carolina

A: The asteroid belt, with its many small rocky bodies, looks in some ways like the whole inner solar system might have looked roughly 10 to 100 million years after the Sun was born. So why doesn't the asteroid belt condense and form a planet? **First of all, there's not enough total mass in the belt to form a planet. Second, the belt is too close to Jupiter.**

We haven't counted every tiny asteroid by a long shot, but we can estimate the mass of the belt from the asteroids we see and by monitoring the orbits of both Mars and Earth. The belt contains only about 4 percent of the Moon's mass in asteroids — not enough to form a planet-sized body.

Why is there so little mass in the asteroid belt? And why didn't a planet form there when, say, Earth was forming?

Jupiter stirs up the asteroid belt through dynamical effects called "mean motion resonances." A mean motion resonance happens when the orbit of an asteroid has the right period so the asteroid closely encounters a planet at the same location in the solar system over and over again. When this happens between the asteroid and Jupiter, Jupiter's gravitational tugs on the asteroid add up and reinforce each other, and they can easily boot the asteroid out of the solar system.

These resonances (and other kinds of perturbations associated with Jupiter and Saturn) probably stripped the ancient asteroid belt of most of its mass. So the asteroids we see today are the few survivors that somehow escaped Jupiter's grasp. — **Marc J. Kuchner,** NASA's Goddard Space Flight Center, Greenbelt, Maryland

CREATING GLOBULAR CLUSTERS

Q: How do globular clusters form? Can such massive concentrations of stars arise from gas clouds alone, or is a central black hole required? — **Derek Leaist,** Cloverville, Nova Scotia

A: Exactly how these globular clusters form has been a question for decades. It is not easy for them to develop, and they appear to require extreme physical conditions. **For such a cluster to form, huge amounts of interstellar material must compress into a tiny volume very quickly.** This requires high pressures and densities, which is one reason astronomers often find infant globular clusters at the sites of galaxy collisions.

When galaxies collide, the pre-existing stars are free to move past each other because they are essentially low-density, point-like particles on the size scales involved. On the other hand, when the gas in one galaxy smashes into that of another with great force, it creates widespread shocks and removes momentum from the gas. As a result, small instabilities form extremely dense pockets of gas. Gravity takes over, and all of the ingredients for intense star formation are in place.

Old globular clusters, such as those living in the halo of the Milky Way, certainly host stellar-mass black holes. However, such black holes are the products of stellar evolution within their clusters and do not influence their clusters' formation. — **Kelsey Johnson,** University of Virginia, Charlottesville

Globular cluster M80, like other globulars, likely formed from condensing clouds of interstellar material. The Hubble Heritage Team (AURA/STScI/NASA)

ORBIT ALTERATION

Q: Why do comets have such eccentric orbits? — **Necati Demiral,** Istanbul, Turkey

A: Comets actually have a wide variety of orbital shapes — and they're not all extremely eccentric. Comets with very eccentric elliptical orbits arrive in the inner solar system from the Oort Cloud — a region thousands of astronomical units (AU, the Earth-Sun distance) away. If it weren't for gravitational perturbations, which are usually a result of coming too close to Jupiter, these comets would return to the Oort Cloud on the same orbit. "Nongravitational forces" — due to the jet-like reactions from outgassing of the comet nucleus itself — also slightly alter the orbit's shape. Both of these forces cause the eccentricity of the comet's orbit to become either smaller or larger; the latter case sometimes results in the comet completely escaping from our solar system.

Other comets have less-elongated orbits. Some of them lie among the outer planets, and others are trapped inside Jupiter's orbit. Most comets with less-elongated orbits originated in the Kuiper Belt — the region beginning near Neptune and extending perhaps to several hundred AU. Some objects even have low-eccentricity orbits — meaning they're close to circular. Interestingly, in 1927 scientists discovered that Comet Schwassmann-Wachmann 1 is in a near-circular orbit just beyond Jupiter. — **Dave Schleicher,** Lowell Observatory, Flagstaff, Arizona

What's the Sun's highest temperature? Find out at www.Astronomy.com/toc.

COSMIC CONFUSION

Q: Dark energy is consistently described as a property of space itself. Does this mean that, in the total absence of matter, the universe would still exist? — **Dennis Demcheck,** Baton Rouge, Louisiana

A: Space can indeed exist without matter or radiation. In our universe, radiation dominated at a time earlier than about 50,000 years after the Big Bang. Then matter dominated until a few billion years ago. After that, dark energy took over. But you could, in principle, have an empty universe without observers or matter or radiation. This is called a Milne universe after Edward Arthur Milne, the cosmologist who first studied it. **So space can exist without regard to what fills it.**

That said, it is not clear that dark energy is a "property of space." We simply do not know what it is that powers the universe's accelerated expansion. It could be that dark energy is due to new particles with unusual properties (remember, they cannot behave like the usual matter particles because then the universe would not accelerate). Or, it could be that the observed accelerated expansion of the universe is due to our incomplete understanding of Einstein's general theory of relativity. In this scenario, the purported acceleration would go away after scientists use the correct modified theory to interpret the observations. Or, dark energy could be something still completely different.

It is becoming clear that our understanding of the universe is incomplete. Whether dark energy is a new particle or a new force, whether we have a new theory of relativity at hand, or whether empty space has small but nonzero energy is one of the most pressing questions of our time. — **Dragan Huterer,** University of Michigan, Ann Arbor

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Tour the Fornax Supercluster

Medium- to large-aperture telescopes reveal dozens of galaxies in this small region of sky.

by Richard Jakiel

Individual galaxies like the Andromeda Galaxy (M31) and Centaurus A (NGC 5128) make great targets through backyard telescopes. Sometimes you can scan a small area of sky and see several galaxies in a group or cluster, such as in Stephan's Quintet (NGC 7317–20). For this article, however, we expand our reach to the supercluster level — specifically, to the Fornax Supercluster.

This vast collection of bright galaxies lies more than 30° southwest of the rich star-forming regions of Orion. Although observers often bypass it for better-known fare in the early winter sky, the Fornax Supercluster offers a spectacular assortment of objects.

Astronomers note its giant ellipticals and impressive barred spirals. It consists of more than 100 bright galaxies lying between 65 and 85 million light-years away. It is the second-richest nearby supercluster (next to the Virgo Supercluster), and it contains galaxy clusters in Fornax and Eridanus plus several smaller galaxy groups.

NGC 908 in Cetus contains huge star-forming regions. It glows at magnitude 10.4, but you will need a 12-inch or larger scope to resolve the spiral arms. George and Laura Mishler/Adam Block/NOAO/AURA/NSF

NGC 1232 in Eridanus is a classic face-on spiral. Although you can glimpse it through a 4-inch telescope, you'll require a larger scope and good seeing to resolve the arms. George Greaney

The Fornax cluster

The Fornax galaxy cluster is the better-known to observers, and it's also the closer of the two main components. This compact group contains dozens of galaxies concentrated in a core about 2° across. But its brightest and most massive member, **NGC 1316** (also known as Fornax A), lies well outside this region. Fornax A is a giant radio galaxy with a supermassive black hole that has been feeding on the remnants of a spiral galaxy it cannibalized 3 billion years ago.

To find this object, starhop 1.4° south-southwest of magnitude 6.4 Chi^1 (χ^1) Fornacis, and look for a bright, condensed nebulous patch. At magnitude 8.8, NGC 1316 is about as bright as the closer M87 in Virgo. Slightly more than 6' north is magnitude 11.9 **NGC 1317**. This object has a double bar, and its secondary bar is more prominent than the primary one.

With a lack of bright stars in the area, the best way to explore the rest of the cluster is to "galaxy hop": Shift your telescope a little more than 2° east-northeast from NGC 1316 to locate the sky's largest barred spiral, beautiful **NGC 1365**. This impressive sight has a prominent central bar and two massive arms. A 10-inch telescope will begin to resolve the spiral structure. Through my 17.5-inch scope, I can see dark dust rifts in the bar cutting into the brilliant core region. The spiral arms resolve well, and I even can discern some of the brighter HII regions (glowing hydrogen clouds).

Sweep your telescope 1° northeast to locate the cluster's dense core. Two giant ellipticals — **NGC 1399** and **NGC 1404** — dominate the region. Both are magnitude 10 objects less than 10' apart, forming a perfect hop-off point for the rest of the cluster. Through a small scope, they appear as round, fuzzy nebulae.

Between this pair and NGC 1365 is a north-south trending chain of a dozen

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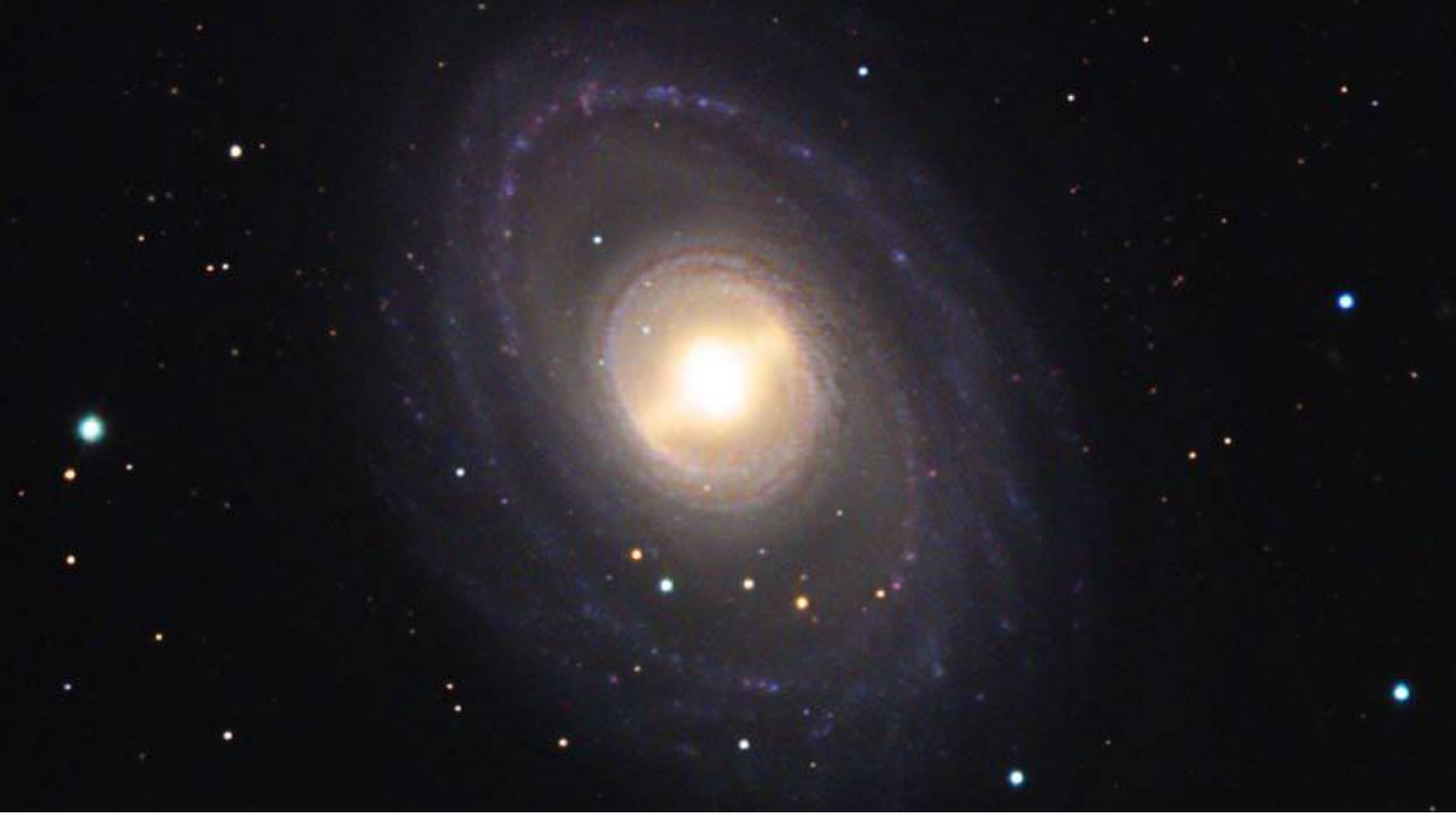
Richard Jakiel *has observed the deep sky for 30 years. His most recent book is* Galaxies and How to Observe Them *(Springer, 2006).*



NGC 1398 in Fornax is one of the sky's finest face-on spiral galaxies. This object shines brightly at magnitude 9.8. Unfortunately, the galaxy's core is so bright that it masks its delicate spiral arms when viewed through small telescopes or with low magnifications. Sean and Renee Stecker/Adam Block/NOAO/AURA/NSF

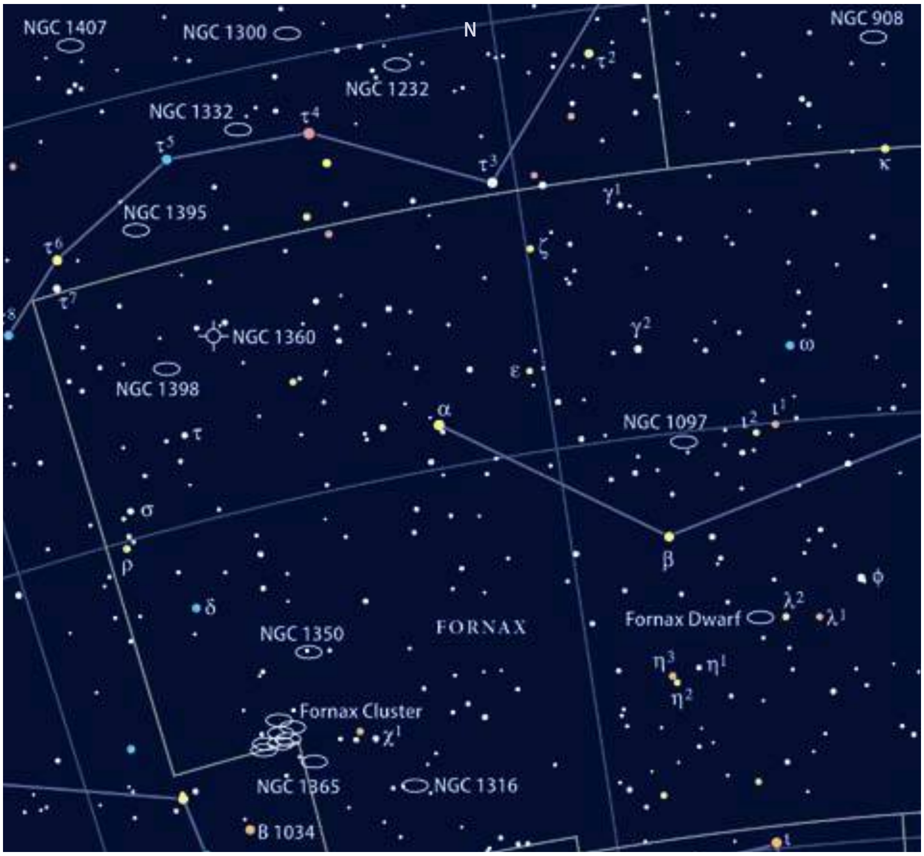
11th- and 12th-magnitude galaxies. Elliptical and lenticular galaxies populate this 1.5°-long chain. As often is the case in dense galaxy clusters, large spirals are scarce in the central regions. A process astronomers call ram stripping, where the gravitational interactions of galaxies expel their interstellar gas, has left mostly stars in many of these galaxies, thus affecting their evolutions.

Located at the north end of the chain is the bright lenticular galaxy **NGC 1380**. Through my 12-inch scope, it appears as a small, diffuse, elongated oval with a bright core.

Just 20' to the southwest of NGC 1380 is a neat little trio centered on the 11th-magnitude elliptical **NGC 1374**. A couple arcminutes south is the lenticular galaxy **NGC 1375**, while a fainter elliptical (**NGC 1373**) lies 5' northwest of the central galaxy. Through an 8-inch telescope, this is a nice little group to examine at medium to high power.

The Eridanus cluster

The Eridanus cluster is considerably larger and sprawls out more than its Fornax counterpart. Lying 85 million light-years away, its members appear generally



Use this finder chart to locate the galaxies described in this story. The tight grouping near the bottom labeled "Fornax Cluster" contains NGC 1373, NGC 1374, NGC 1375, NGC 1380, and NGC 1404. The brightest star in this region is Tau^4 (τ^4) Eridani, at magnitude 3.7. Alpha (α) Fornacis is nearly as bright, with a magnitude of 3.9. Note: NGC 1360 is a planetary nebula. *Astronomy*: Richard Talcott and Roen Kelly fainter. However, being at least 10° higher in the sky for Northern Hemisphere observers makes it easier to explore. Its members loosely segregate into northern and southern sections, unlike the highly concentrated Fornax cluster.

Begin by exploring the cluster's northern portion. On the far western fringe lies the large face-on spiral **NGC 1232**. Its unusual angular spiral arms led to this galaxy's inclusion (as number 41) in American astronomer Halton Arp's *Atlas of Peculiar Galaxies*.

Astronomers think gravitational effects of the small satellite NGC 1232A have warped the larger galaxy's arms. To find NGC 1232, first locate magnitude 3.7 Tau^4 (t^4) Eridani, and then move your telescope 2.6° west-northwest. At low power or through a smaller telescope, NGC 1232 appears as a round, diffuse 10th-magnitude glow about 5' across with a brighter oval core. Through my club's 24-inch scope, NGC 1232's arms are clearly visible and I can resolve some of the brighter HII regions.

About 2.3° due north of Tau^4 Eridani is the archetypal barred spiral **NGC 1300**. The bright central bar is about 3' long, and a massive arm lies on each end. You'll see the galaxy's oval shape through small scopes, while some observers have reported resolving the arms through apertures as small as 10 inches.

Perhaps due to lower overall density, the number of giant elliptical and lenticular galaxies is fewer in the Eridanus cluster than in the Fornax cluster. Two giant ellipticals, **NGC 1400** and **NGC 1407**, lie in the northern region, about 5° west of NGC 1300. NGC 1400 shines at magnitude 10.9 while NGC 1407 is a magnitude brighter. Both are round fuzzballs with bright cores. Several 11th- to 12th-magnitude galaxies lie within 1° and are worth looking at.

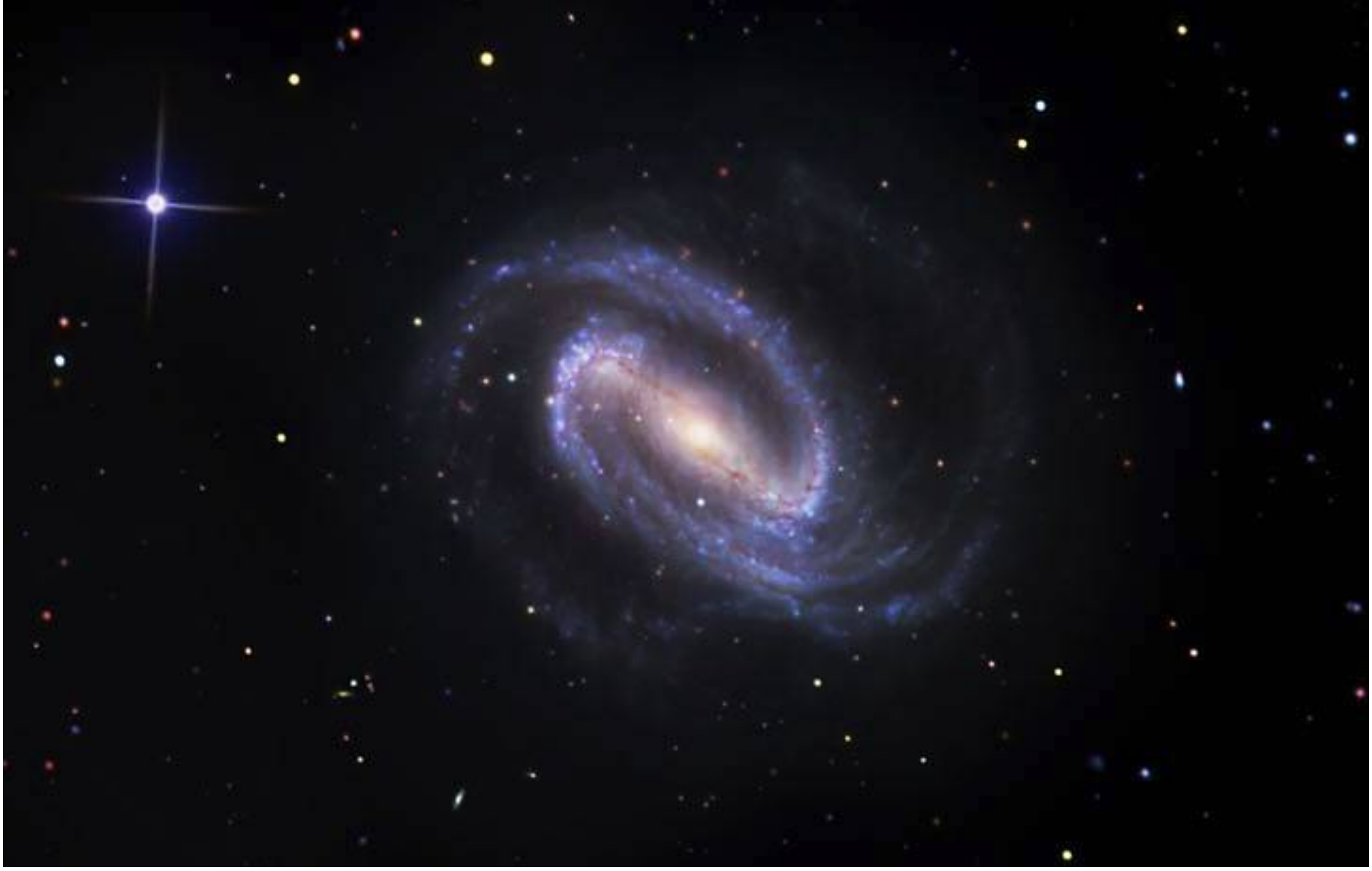
Lenticular **NGC 1332** lies at the center of another small group just north of the halfway point along a line between Tau^4 Eridani and magnitude 4.3 Tau^5 Eridani. A classic football-shaped galaxy, its high surface-brightness makes it an easy target. In the center of the Eridanus cluster's southern core is **NGC 1395**, a magnitude 9.8 giant elliptical. It has a high surface-brightness, so it makes an excellent starting point to explore a scattered group of magnitude 12 objects to the northeast.

NGC 1365 in Fornax is the southern sky's finest barred spiral galaxy. Through even a 4-inch telescope at a dark site, you'll see NGC 1365's bar shape and brighter central region. Don Goldman

Member galaxies of the Fornax Supercluster

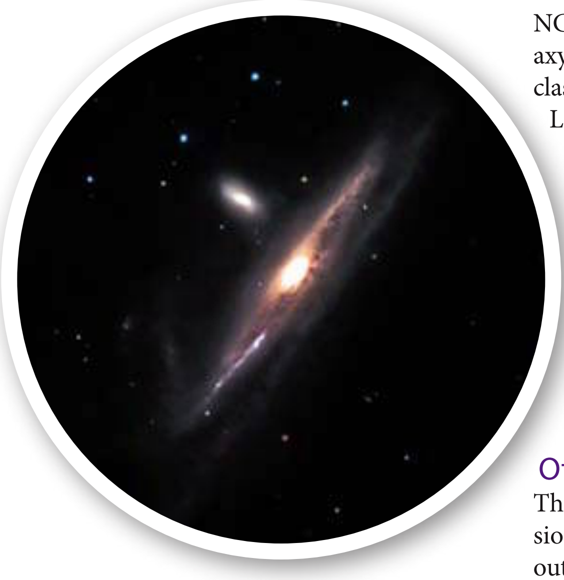
Designation	Constellation	R.A.	Dec.	Mag.	Size
NGC 908	Cetus	2h23m	–21°14'	10.4	5.9' by 2.3'
NGC 1232–32A	Eridanus	3h10m	–20°35'	10.0	6.8' by 5.6'
NGC 1300	Eridanus	3h20m	–19°25'	10.4	5.5' by 2.9'
NGC 1316–7	Fornax	3h23m	–37°12'	8.8	11' by 7.6'
NGC 1332	Eridanus	3h26m	–21°20'	10.5	5' by 1.8'
NGC 1365	Fornax	3h34m	–36°08'	9.3	8.9' by 6.5'
NGC 1371	Fornax	3h35m	–24°56'	10.7	5.6' by 3.9'
NGC 1373	Fornax	3h35m	–35°10'	12.4	1.2' by 0.9'
NGC 1374	Fornax	3h35m	–35°14'	11.0	2.6' by 2.4'
NGC 1375	Fornax	3h35m	–35°16'	12.2	2.3' by 0.9'
NGC 1380	Fornax	3h37m	–34°59'	10.0	4.8' by 2.8'
NGC 1395	Eridanus	3h39m	–23°02'	8.9	11' by 7.6'
NGC 1398	Fornax	3h39m	–26°20'	9.8	7.2' by 5.2'
NGC 1399	Fornax	3h39m	–35°27'	9.9	8.1' by 7.6'
NGC 1400	Eridanus	3h40m	–18°41'	10.9	2.5' by 2.1'
NGC 1404	Fornax	3h40m	–35°35'	9.7	4.8' by 3.9'
NGC 1407	Eridanus	3h40m	–18°35'	9.8	4.6' by 4.3'
NGC 1531–2	Eridanus	4h12m	–32°52'	9.9	11.2' by 3.2'

Key: R.A. = Right ascension (2000.0); Dec. = Declination (2000.0); Mag. = Visual magnitude



NGC 1300 in Eridanus has the shape of a squashed backward letter S. It's a classic barred spiral with two arms that originate from the bar and move out at right angles from it. At magnitude 10.4, NGC 1300 is an easy target from a dark site, but you'll need a 10-inch scope to see the arms well. R. Jay GaBany

Lying in the southern fringes of the Eridanus cluster are two other spiral galaxies. About 2° south-southwest of NGC 1395 is magnitude 10.7 **NGC 1371**. Presented not quite face-on, it is distinctly oval. The central bar isn't as pronounced as in previously mentioned galaxies, but it does have a condensed core. This object is relatively easy to see through a typical 8-inch scope.



NGC 1532 in Eridanus is a double galaxy. It combines a magnificent magnitude 9.9 edge-on spiral with magnitude 11.7 elliptical NGC 1531, which sits less than 2' to the northwest. But NGC 1532 is the real treat here. It appears nearly 6 times as long as it is wide. Ted Wolfe

Less than 2° to the southeast, and forming one apex of a right triangle that includes the unusual planetary nebula NGC 1360, is the magnificent face-on galaxy **NGC 1398**. One of the finest of its class, it bears some resemblance to M95 in Leo. Both have the *Star Wars* "Tie Fighter" shaped inner region consisting of a bright bar and an inner ring. A larger outer region of spiral arms surrounds them both, although in NGC 1398's case the arms are thinner and more defined. The bright inner region is easy to see through most telescopes, but resolution of the delicate outer arms is far more difficult.

Other galaxy groups

The Fornax Supercluster has its own versions of our Local Group occupying its outer regions. The westernmost group centers on the large inclined spiral **NGC 908**, just across the border in Cetus. This magnitude 10.4 starburst galaxy is undergoing a massive amount of star formation. Its spiral arms are thick and patchy. The core region is small and bright. NGC 908 isn't better known because it's basically in the middle of nowhere. To locate this galaxy, look 5.4° east of magnitude 4.0 Upsilon (υ) Ceti.

Our last stop is the **NGC 1532** group. On the southeastern fringe of the supercluster, the main system is a huge interacting galaxy, classified as a Whirlpool (M51) type galaxy seen edge-on. Measuring 11.2' x 3.2', it rivals NGC 1365 as the supercluster's largest galaxy. Through an 8-inch telescope, it takes on the appearance of a large edge-on galaxy, complete with a bisecting equatorial dust lane. A 12-inch instrument will reveal the magnitude 11.7 dwarf lenticular galaxy, NGC 1531, off the western arm. You'll find this pair 1.5° northwest of magnitude 3.6 Upsilon^4 (υ^4) Eridani.

I've touched only on the brighter, better-known members of the Fornax Supercluster. Dozens of galaxies are within reach of a high-quality 8-inch scope under a dark sky, and this number climbs into the hundreds for owners of giant Dobsonian-mounted reflectors. By steering your scope off the beaten track, you can explore one of the less-traveled paths of the night sky.

Target **40** wonderful winter sky treats

The winter sky is loaded with great deep-sky objects. Through your telescope, you can pick them off like ornaments on a celestial tree.

by Michael E. Bakich

I hear it all the time: "I want more objects to observe." So, in the spirit of holiday giving, here's a quick look at 40 great winter deep-sky treats. I've included 12 star clusters, 13 nebulae, 11 galaxies, and four miscellaneous objects. I've also added a bonus list of 10 double stars you'll enjoy observing.

Those of you with go-to telescope drives can whip through this list in no time. But spend at least a few minutes with each target, observing what makes it a great sight. Go-to drives enable you to go back and forth between two favorites quickly, comparing their sizes, brightnesses, colors, and more. Because I chose reasonably bright objects, owning a telescope not equipped with a go-to drive shouldn't slow you down much.

Start with star clusters

Although you can spot the **Double Cluster** in Perseus with your naked eyes, this pair is a treat through low-power optics. NGC 869 is the westernmost and the richer of the two clusters. It contains nearly three dozen magnitude 9 and 10 stars in an area 10' across.

NGC 884 appears less concentrated but holds more bright stars. Through a 4-inch telescope at 50x, you'll see an abundance of color in these stellar jewels. Look for red, yellow, and blue gems scattered among the many white stars.

Each cluster holds a treasure at its core. NGC 869 contains a dark, Y-shaped rift. NGC 884's stars surround RS Persei, a deep-red, semiregular variable star.

Our next object is a nice small-scope target: open cluster **M34** in Perseus. Although this is one of Messier's objects — and a bright one at that — amateur astronomers often overlook it.

You'll find M34 roughly 5° west-northwest of Algol (Beta [β] Persei). This magnitude 5.2 cluster contains 10 stars brighter than 9th magnitude spread out over an area 35' across. That's a bit bigger than the Full Moon.

From magnitude 0.9 Aldebaran (Alpha [α] Tauri), move 3.5° northeast to magnitude 6.4 **NGC 1647** in Taurus.

Adam Block/NOAO/AURA/NSF

Globular cluster M79 in Lepus can prove difficult to resolve through small instruments. Be patient, however, and use as much magnification as the sky steadiness will allow.

You'll see 30 stars through a 4-inch telescope, and increasing the aperture increases the number of stars. Crank the magnification past 150x, and look for lots of nice, close binary stars.

Globular cluster **M79** lies in the small constellation Lepus the Hare, which lies directly south of Orion. To spot M79, draw a line from magnitude 2.6 Alpha Leporis through magnitude 2.9 Beta Leporis and extend that line 3.5°, which is

The Double Cluster in Perseus (NGC 869 and NGC 884) is easy to spot without optical aid from a dark site, but it really pops through binoculars or a telescope that gives a wide field of view. Thomas V. Davis

Open cluster M35 in Gemini is bright enough to see with your naked eyes. Through a telescope, M35 features more than 100 stars and an additional open cluster — NGC 2158 (right). Dietmar Hager

The Crab Nebula (M1) is not technically a nebula, but rather a supernova remnant. In 1054, a brilliant new star 4 times brighter than Venus appeared near Taurus the Bull's southern horn. For more than 3 weeks, it remained visible during daylight hours, and it took more than a year to fade from view. Today, we can point our telescopes toward this area of sky and see a roiling, twisted mass of expanding stellar material. R. Jay GaBany

just slightly more than the distance between those two stars.

Although it shines at magnitude 7.8, M79 is difficult to resolve through small telescopes. A 10-inch instrument shows that the 8.7'-wide globular has a bright, broadly concentrated core with few individual stars visible. Crank up the magnification beyond 250x, and you'll resolve scores of stars as bright as 13th magnitude at the cluster's edges.

Through any size telescope, **M37**, also known as the Salt-and-Pepper Cluster, displays an even distribution of stars. Although it sits within the Milky Way in Auriga, M37's edge is easy to discern.

A 3-inch scope reveals 50 stars. The brightest member — a magnitude 9 orange star — sits near the center.

With many open clusters, increasing the size of the telescope worsens the view; as the cluster gets magnified, the stars thin. Also, larger scopes reveal more background stars, making it harder to see the cluster's outline.

Not with M37. With this wonder, larger scopes reveal only more stars. Through a 10-inch scope, you'll count 200 stars, and a 16-inch will reveal 500.

It's hard to resist a two-for-one sale, and **M35** offers just that. It lies 2.3° northwest of magnitude 3.3 Eta (η) Geminorum. Point a telescope at M35, and not only will it explode into stars, but you'll also see a second open cluster.

M35 contains two dozen stars brighter than 9th magnitude. Most reside near the cluster's center. In this region, look for a string of stars some 10' long shaped like a saxophone. Fainter members push the total number of visible stars above 200.

If you use a low-power eyepiece to engulf M35, **NGC 2158** will look like a small, fuzzy magnitude 8.6 ball. This cluster rewards high magnification. Through a 14-inch telescope at 500x, you'll count 30 stars. Increase the aperture to 20 inches, however, and you'll double that number.

To find the **37 Cluster** (NGC 2169) in Orion, first locate magnitude 4.5 Xi (ξ) and magnitude 4.4 Nu (ν) Orionis. The cluster forms the southern tip of an isosceles triangle roughly 0.8° from each star.

The cluster isn't huge — it spans only 6' — but it contains seven stars brighter than 9th magnitude. Use an eyepiece that gives a 1° field of view to enjoy a wide view of NGC 2169 against the Milky Way's myriad background stars.

The common name the "37 Cluster" comes from imaginative observers viewing this object at low power and seeing the number 37 in it. To find the 37, you need to observe it with north up and east to the left. Also, a telescope/eyepiece combination that yields a field of view of about 0.25° works best.

M41 is one of the easiest deep-sky targets to find because you can use the sky's brightest star as a guide to it. This open cluster lies 4° south of Sirius (Alpha Canis Majoris). From a dark site, you'll easily spot M41 with your naked eyes.

Through a 6-inch scope, you'll see about 50 stars. Star counts by astronomers indicate M41 contains slightly more than 100 member stars strewn over an area about the size of the Full Moon.

The brightest star in the field of view, 12 Canis Majoris, does not belong to the

The Flaming Star Nebula (IC 405) lies in southwestern Auriga. Most nebulae glow because a bright star or star cluster formed within their midst. Ultraviolet radiation excites hydrogen atoms, causing them to glow. In the Flaming Star Nebula, the star AE Aurigae (upper center) is the power source. Gerald Rhemann and Michael Jäger

cluster. At a distance of 1,100 light-years, 12 CMa lies less than half as far away as M41. This magnitude 6.1 star sits 21' southeast of M41's center.

Observers named the **Tau Canis Majoris Cluster** (NGC 2362) for the brightest star it contains, magnitude 4.4 Tau (τ) CMa. None of this cluster's other stars shines within 3 magnitudes of Tau. To locate NGC 2362, find magnitude 1.8 Wezen (Delta [δ] Canis Majoris), and move 2.7° to the east-northeast.

Through a telescope, Tau dominates the view, partially obscuring many of the 10th-magnitude stars surrounding it. To get an accurate count of the stars in NGC 2362, place Tau just outside the field of view, first to the north, followed by each of the other three cardinal directions. Then, count the suddenly visible fainter stars, and add the four numbers together.

The Intergalactic Wanderer (NGC 2419) lies in a region of southwestern Lynx devoid of bright stars. To locate it, find magnitude 1.6 Castor (Alpha Geminorum), and move 7° due north.

This object isn't famous for its beauty through a telescope, but rather because it's one of the Milky Way's most remote globular clusters. It lies some 300,000 light-years from our galaxy's core and only 25,000 light-years closer to us.

A 4-inch telescope reveals scant detail in NGC 2419, but you will see it. Through an 8-inch or larger scope at 200x or above, look for an ever-so-slightly brighter center ringed by an irregularly lit halo.

I think open cluster **M46** in Puppis is one of the sky's top objects. Aim a 4-inch or larger telescope its way, and you'll see why. The star cluster contains several hundred stars. You'll see 100 of them through an 8-inch scope. The stars appear evenly distributed throughout a circle slightly less than 0.5° across.

Within M46's boundaries resides planetary nebula **NGC 2438**. It sits 7' north of the cluster's center and measures about 1' across. Use a 10-inch scope and high power, and you may detect the planetary's doughnut-like appearance.

The Eskimo Nebula (NGC 2392) in Gemini is a bright planetary nebula you'll spot through any telescope. Use high power (above 200x) to bring out its details. Dietmar Hager

Nab these nebulae

The **Bow-Tie Nebula** (NGC 40) makes a fine target through all telescopes because its surface brightness is high. You'll find it 5.5° south-southeast of magnitude 3.2 Gamma (γ) Cephei.

A 4-inch telescope at a dark site will reveal an oval disk about one-third longer than it is wide. The magnitude 11.6 central star appears bright compared to the nebula.

Through a 10-inch scope, NGC 40's disk shows several bright knots toward the southeast and northwest. Increase the magnification to 200x (if the seeing permits), and look for a dark cavity between the shell and the central star.

One of the sky's most famous objects, and a nice small-telescope target, is the **Crab Nebula** (M1) in Taurus. Although the word "nebula" is part of this object's name, astronomers classify M1 as a supernova remnant, the expanding remnants of a massive star that exploded.

This magnitude 8.0 object has high surface-brightness, so even a 3-inch telescope will reveal it. The Crab has an oval shape. It measures 6' by 4' and orients northwest to southeast.

The easiest way to find M1 is to start at blue, magnitude 4 Zeta (ζ) Tauri. From there, move 1° to the northwest.

The **Orion Nebula** (M42) is the sky's second-brightest diffuse nebula. Easily seen from a dark site, sharp-eyed observ-

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Michael E. Bakich *is a senior editor of* Astronomy.

ers can detect this cloudy patch even under moderate light pollution. Large telescopes show M42's full extent, which covers an area 6 times the size of the Full Moon. Although you don't need a nebula filter to enjoy this object, using one at a dark location accentuates the contrast between the light and dark regions.

Only 0.1° north-northeast of the Orion Nebula's center lies **M43**. It is often called De Mairan's Nebula in honor of its discoverer, French mathematician Jean-Jacques D'Ortous de Mairan. Note M43's sharp eastern edge. A dark nebula overlaps that area.

The **Flaming Star Nebula** (IC 405) is a dim wisp of light glowing in Auriga. To observe it, first find the star AE Aurigae, which lies 4.2° east-northeast of magnitude 2.7 Iota (ι) Aurigae. The star's energy causes gas in the nebula to glow.

Through a 6-inch telescope, the Flaming Star Nebula appears triangular in shape, with one point at the star AE Aur. Increase the telescope's aperture and add a nebula filter to improve the nebula's contrast while dimming AE Aur and other field stars.

You'll find reflection nebula **NGC 1999** lying 0.8° south-southeast of magnitude 3.0 Iota Orionis. Such an object shines by reflecting light from a nearby star (or stars). This object's main feature is a dark central obscuration. Crank up the power past 150x, and you'll see the dark inner nebula's triangular form. Just outside the dark cloud sits V380 Orionis, the variable star that illuminates this nebula. To locate it, just look to the east-southeast of the dark central region.

The Rosette Nebula (NGC 2237–9) in Monoceros is a combination object. Here, an open star cluster (NGC 2244) occupies the same space as a beautiful emission nebula. Chris Schur

Spiral galaxy M74 in Pisces is a magnitude 9.4 showpiece. At a distance of 24 million light-years, stellar associations and gas clouds in the spiral arms stand out well, making M74 one of the few galaxies enhanced when you insert a nebula filter into your eyepiece. R. Jay GaBany

Our next target is the sky's brightest reflection nebula: **M78** in Orion. Through a 4-inch scope at 100x, you'll spot an 11th-magnitude star. The two densest parts of M78 lie on either side of this star. If your site is dark, you'll see another, much fainter region of nebulosity, NGC 2067, only 4.5' northwest of M78. A dark lane separates the two.

Our next celestial target combines an emission nebula (NGC 2174) with an open star cluster (NGC 2175), but you'll most often see it referred to as **NGC 2175**. It lies 2.2° southwest of magnitude 3.3 Eta Geminorum in a rich star field. NGC 2175 is a roughly circular object with an indentation on its western side.

A 4-inch telescope will reveal NGC 2175, but you'll need a 16-inch or larger scope to see the full extent of this object. The 7th-magnitude star at the nebula's center is a chance alignment. It lies much closer to us than NGC 2174. Use a nebula filter such as an Oxygen-III (OIII) to reduce the star's glare and improve the nebula's contrast.

Most observers recognize the magnificent **Rosette Nebula** (NGC 2237–9 and NGC 2246) in Monoceros as a single deep-sky wonder. But it's not. From a dark site, you'll first spot open cluster NGC 2244. A 4-inch telescope will reveal some two dozen stars in an oval region elongated northwest to southeast; a half dozen of them surpass 8th magnitude.

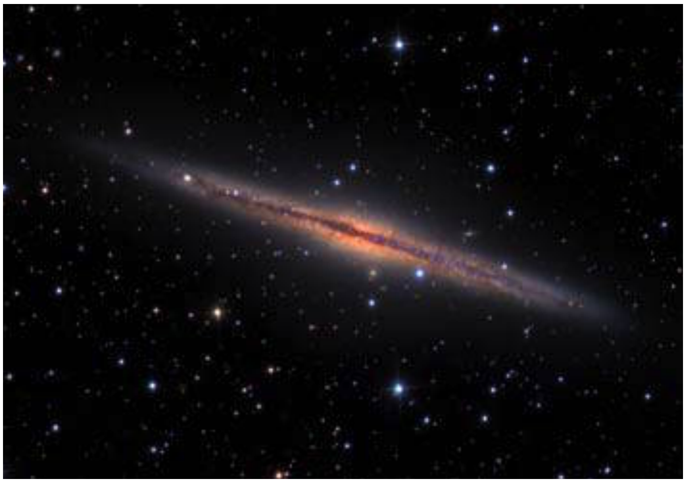
To best observe the nebula's components, use a magnification of 50x and insert a nebula filter to dim NGC 2244's stars. The nebula's western side appears brighter. Here, the ring's inner wall appears straight with a bit of scalloping; the thin outer wall has an extension to the northwest. The Rosette's eastern side is wider. A nebulous wall with a well-defined border forms its northern edge.

Thor's Helmet (NGC 2359) — perhaps the most impressive name for any deep-sky object — formed when radiation from a luminous star sculpted a cosmic bubble. NGC 2359 lies 4.3° northeast of magnitude 4.1 Muliphain (Gamma Canis Majoris).

The nebula responds well to narrowband and nebula filters. Through a 12-inch telescope, you'll see the circular central area and the helmet's two "wings." The brightest part measures 1' wide and extends to the south approximately 4'.

Our next object is the **Eskimo Nebula** (NGC 2392). Through a medium-sized telescope, this planetary nebula resembles a face surrounded by a fur parka.

To find the Eskimo Nebula, point your scope 2.4° east-southeast of magnitude



Edge-on spiral NGC 891 in Andromeda, also called the Silver Sliver Galaxy, is second in appearance only to the Andromeda Galaxy (M31) in that constellation. NGC 891's western section glows slightly brighter. Ken Crawford

Spiral galaxy NGC 2207 in Canis Major interacts with another spiral, IC 2163. The two galaxies glow at magnitudes 10.8 and 11.7, respectively, and lie only 1.5' apart. Thalia and Norman Terrell/Adam Block/NOAO/AURA/NSF

3.5 Delta Geminorum. The planetary glows at magnitude 9.1, which means you can spot it through just about any scope.

Seeing detail in this object, especially through 10-inch or larger scopes, is easy. Use as high a magnification as sky conditions warrant. You'll easily spot the planetary's 10th-magnitude central star.

NGC 2392 has a double-shell. The inner shell appears bright, with a mottled texture. The outer shell looks fainter than the inner one, and a dark ring separates the two. The outer shell also dims with increasing distance from the central star.

Planetary nebula **NGC 2440** lies 8.5° northwest of magnitude 2.8 Rho (ρ) Puppis, or a little more than 3° south of M46. A 4-inch scope shows NGC 2440 as an oval disk oriented northwest to southeast with high surface-brightness.

Because this object glows at magnitude 9.4, you can use high magnifications on it. A 12-inch scope at 300x will help you begin to resolve two lobes, with the northeastern one appearing brighter. Look for a faint haze surrounding the bright inner disk.

Go for the galaxies

Like nebulae, galaxies require a dark sky to see well. Unlike nebulae, most do not respond to astronomical filters because a galaxy's light (which is mainly stars) encompasses the full spectrum. Using a filter, therefore, blocks too much light.

For our first galaxy, head 1.3° east-northeast of magnitude 3.6 Eta Piscium, and you'll find the gorgeous face-on spiral **M74**. Through an 8-inch telescope, you can see the uneven spiral arms and the mottled halo that surrounds the bright core. The half-dozen stars superimposed on the galaxy's glow make it a more impressive sight.

NGC 891 in Andromeda the Princess ranks as one of the sky's best edge-on galaxies. It inclines only 1.4° to our line of sight. A 10-inch telescope reveals a symmetrical object about 10' long with a noticeable, but narrow, central bulge. A dark dust lane bisects the galaxy and runs nearly its entire length.

NGC 1023 in Perseus measures 3 times as long as it is wide, stretching east to west. Through small telescopes, the core appears almost starlike. Use a 14-inch or larger scope, however, and you'll see that the central region spans half of this magnitude 9.3 galaxy's overall length.

The central area of **M77** in Cetus, one-third its total width, commands observers' attention. Although you can spot this spiral through any telescope, a 10-inch or larger instrument will reveal detail around the bright core. Search the disk for mottled structure.

Our next object, **NGC 1097** in Fornax, is a bright barred spiral that sits 2° north of magnitude 4.5 Beta Fornacis. Through an 8-inch telescope, you'll see NGC 1097's core as a bright disk surrounded by an oval haze. Within that oval is the galaxy's faint bar. You won't see much of the thin spiral arms no matter what scope you observe through.

Through even a 4-inch scope at a dark site, look to Fornax for **NGC 1365**'s bar shape and bright central region. Increase the power beyond 150x to see how the bar appears dimmer near the core.

An 8-inch scope shows the spiral arms. The brighter one extends northward from the bar's west end. The other

A bonus! 10 great multiple stars to aim for

Name	Constellation	R.A.	Dec.	Mags.	Sep.	Colors
Mesarthim (γ Arietis)	Aries	1h54m	19°18'	4.6/4.7	7.8"	White/white
Almach (γ Andromedae)	Andromeda	2h04m	42°20'	2.2/5.0	9.8"	Yellow/blue
Polaris (α Ursae Minoris)	Ursa Minor	2h32m	89°16'	2.0/9.0	18.3"	Yellow/blue
Rigel (β Orionis)	Orion	5h15m	–8°12'	0.1/6.8	9"	White/purple
Mintaka (δ Orionis)	Orion	5h32m	–0°18'	2.2/6.3	53"	White/blue
Beta (β) Monocerotis	Monoceros	6h29m	–7°02'	4.7/5.2/6.1	7"/3"	White/white/white
Adhara (ε Canis Majoris)	Canis Major	6h59m	–28°58'	1.5/7.4	7.5"	Blue/white
Wasat (δ Geminorum)	Gemini	7h20m	21°59'	3.5/8.2	6.8"	White/blue
Castor (α Geminorum)	Gemini	7h35m	31°53'	1.9/2.9	3.9"	White/orange
Iota (ι) Cancri	Cancer	8h47m	28°46'	4.2/6.6	30"	Yellow/blue

Key: R.A. = Right ascension (2000.0); Dec. = Declination (2000.0); Mags. = Visual magnitudes; Sep. = Separation arm, only slightly fainter, appears somewhat blotchy, revealing huge star-forming regions within it.

Our next target is **NGC 2146** in Camelopardalis, a spiral galaxy undergoing a major burst of star formation. Finding it without a go-to drive isn't easy because of the lack of bright stars in the area. Look 11.6° northeast of magnitude 4.6 Gamma Camelopardalis. NGC 2146 displays a broad central region. Telescopes with apertures larger than 10 inches show some mottling close to the core and a dark, subtle lane near the southwestern edge.

Move to magnitude 2.0 Mirzam (Beta Canis Majoris), and pan south-southwest 4° to **NGC 2207**, a spiral galaxy interacting with its neighbor, the spiral IC 2163. Through a 10-inch telescope, NGC 2207 shows a thin halo surrounding a bright core. The galaxy orients east-west. IC 2163 lies 1' east and shows a broadly concentrated glow 2' across.

Our next object, **NGC 2217**, also is a spiral galaxy in Canis Major. A 12-inch telescope at 250x shows a short bar elongated east-west. The magnitude 10.2 galaxy has an even brightness distribution across its central region. To the north and south you may see the faint halo.

NGC 2336 sits in a star-poor region of Camelopardalis, 15° north-northeast of Gamma Cam. A small telescope shows this barred spiral galaxy's bright central region surrounded by an easily seen halo. Through a 10-inch scope at 200x, you'll see NGC 2336's bar.

NGC 2403 in Camelopardalis is one of the sky's brightest galaxies, shining at magnitude 8.2. It's large, however, so that brightness spreads over an area 25' long by 13' wide. To find it, look 7.7° northwest of magnitude 3.4 Muscida (Omicron [o] Ursae Majoris).

Small telescopes show this object as an indistinct haze roughly twice as long as wide, with a bright central region. Through a 12-inch scope, you'll begin to see the galaxy's spiral arms.

NGC 2403 in Camelopardalis is a huge galaxy, some 25' long. That's nearly as wide as the Full Moon. A 12-inch or larger telescope will let you see stellar associations along NGC 2403's spiral arms. Tony Hallas

Don't miss the miscellaneous

You'll find our next target in Lepus near that constellation's border with Eridanus. It lies 3.5° west-northwest of magnitude 3.3 Mu (μ) Leporis. **Hind's Crimson Star** (R Leporis) is one of the sky's reddest points of light, especially when it nears minimum brightness, which it will again do in May 2010. Its magnitude varies from a naked-eye 5.5 down to 11.7. To spot its color, use low magnification. When you've centered R, ever-so-slightly defocus the image to spread out the star's color, making it easier to see.

Algol (Beta Persei) is the sky's most famous variable star. It normally shines at magnitude 2.1. Every 2 days, 20 hours, and 49 minutes, however, its light diminishes to magnitude 3.4. So, at maximum, Algol is 3.3 times as bright as when it's at its minimum. This dip in brightness occurs when a faint, unseen star orbiting Algol passes in front of it and blocks some of its light. Each eclipse lasts approximately 10 hours.

A nice small-telescope target is the unusually named **9–12 Geminorum Cluster**. The name refers to numbers the first British Astronomer Royal, John Flamsteed, gave to four stars during his surveys of the constellations.

So, the four stars in the 9–12 Geminorum Cluster are 9, 10, 11, and 12 Geminorum. Their magnitudes are 6.3, 6.6, 6.9, and 7.0, respectively. This 1°-wide cluster, which has a total listed magnitude of 5.7, also carries the designation Collinder 89. It lies about 1.5° northwest of magnitude 2.9 Mu Geminorum.

To find **NGC 2451**, look 4.1° west-northwest of magnitude 2.2 Naos (Zeta Puppis). There you'll find one of the sky's brightest apparent open clusters. Astronomers have plotted the motions of the stars here, and they are not traveling through space together.

Hind's Crimson Star (R Leporis) is a type of variable star known as a carbon star. Carbon buildup in the star's upper atmosphere dims and reddens its light. R Leporis appears reddest when at minimum brightness, which occurs about every 14.5 months. Al Kelly

Through a telescope, use a low-power eyepiece. You'll see 15 bright stars around orange magnitude 3.6 SAO 198398, which sits dead-center.

As you locate these 40 deep-sky treats, keep in mind that I've only scratched the surface of the winter sky. Hundreds more await you through any telescope. View each target carefully, and in no time you'll be a seasoned deep-sky observer.

You'll find more images of these objects at www.Astronomy.com/toc.

Equipment review

Astronomy tests a hot new spectroscope

You may have seen sunspots and prominences, but have you observed the Sun's spectrum? The Lhires Lite spectroscope makes such observations easy. **by Mike D. Reynolds**

LHIRES Lite
by Shelyak INSTRUMENTS
WWW.SHELYAK.COM
Series 500 PLÖSSL

The Lhires Lite spectroscope allows you to view the spectrum of the Sun and other bright light sources quickly, easily, and in great detail.

Amateur solar observing has an exciting new tool. The Lhires Lite spectroscope breaks sunlight into a rainbow of colors crossed by dark lines. For two centuries, professional astronomers have used such devices to identify what stars are made of, tell how a star is moving through space, and a lot more.

The manufacturer, Shelyak Instruments, located in Revel, France, designed this device to allow amateur astronomers to study the Sun's spectrum. I found the Lhires Lite to be an affordable and enjoyable entry into the world of spectroscopy. The device is completely safe to use when observing the Sun.

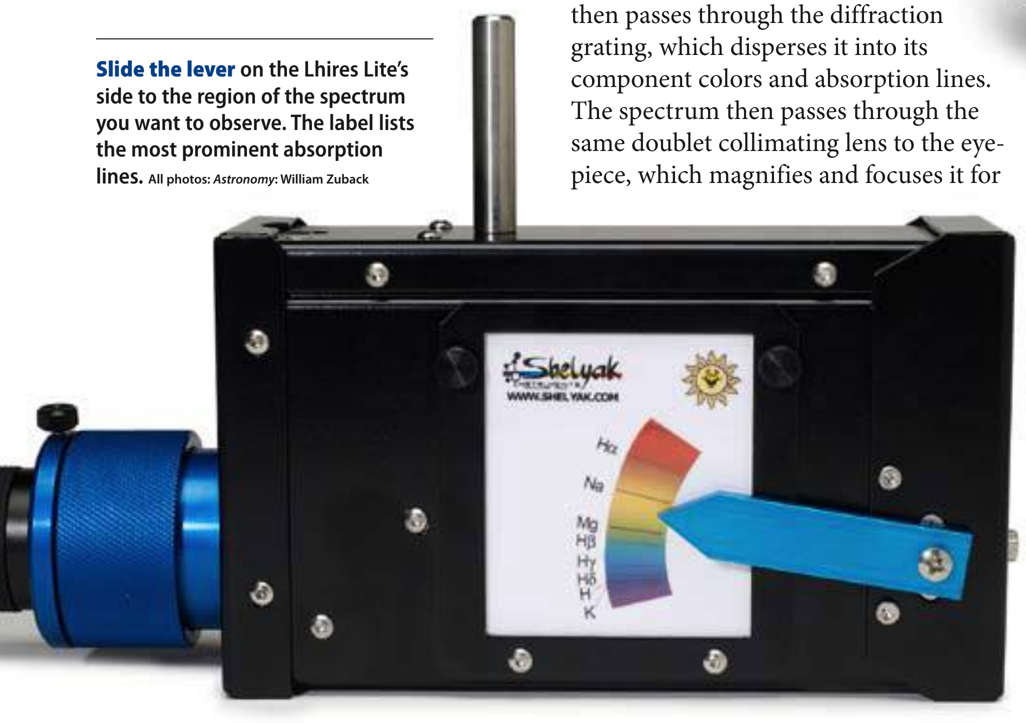
Product highlights

The Lhires Lite comes packaged in a custom aluminum case. The instrument mounts on a camera tripod's head via the standard connector. A rod on the top side of the Lhires Lite acts as a gnomon, a device to help center the Sun. Simply move the instrument until the gnomon produces no shadow. The spectroscope then points at the Sun.

The Lhires Lite is an f/50 instrument containing a diffraction grating with 2,400 grooves per millimeter. The package includes a 25mm 1¼" Plössl eyepiece. This setup produces a highly magnified image, so only a small part of the Sun's spectrum is visible through the eyepiece. But with a lever on the side, you can sweep across the Sun's entire spectrum.

Splitting sunlight

The Lhires Lite is a Littrow, or auto-collimating, spectroscope. Sunlight goes into the instrument through a narrow slit. The spreading light is reflected off a 45° mirror to a doublet collimating lens, which makes the light beam parallel. It then passes through the diffraction grating, which disperses it into its component colors and absorption lines. The spectrum then passes through the same doublet collimating lens to the eyepiece, which magnifies and focuses it for viewing. Lhires is an acronym for Littrow high-resolution spectroscope.



Slide the lever on the Lhires Lite's side to the region of the spectrum you want to observe. The label lists the most prominent absorption lines. All photos: *Astronomy*: William Zuback

Adjusting the visible part of the solar spectrum is quite easy, a nice Lhires Lite design feature. On the side of the instrument is a lever that controls the instrument's diffraction grating. Beneath the lever is a scale card that shows the color and wavelength of the absorption lines you can observe. Shelyak includes additional scale cards; instructors can use blank scale cards for classroom activities.

Observing the Sun

My first view through the Lhires Lite was surprising and, quite frankly, breathtak-

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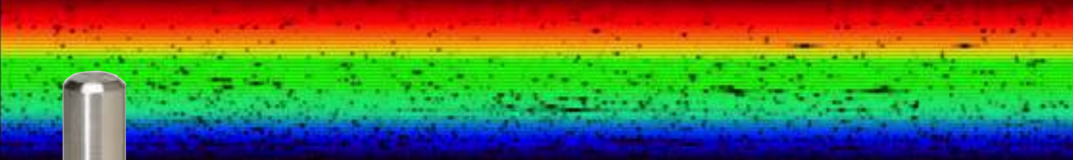
Mike D. Reynolds, *a contributing editor of* Astronomy, *is the Dean of Liberal Arts & Sciences at Florida State College at Jacksonville.*


N.A.Sharp, NOAO/NSO/Kitt Peak FTS/AURA/NSF

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Hα
Na
Mg
Hβ
Hγ
Hδ
H
K

ing. I did not expect to see such vibrant spectral colors or the Sun's absorption lines so clearly. These lines carry the name Fraunhöfer lines for Joseph von Fraunhöfer, who first cataloged some 570 of them. Absorption lines are specific wavelengths at which elements in the Sun's atmosphere absorb photons. This activity produces fine, dark lines. In the Sun, energy emitted in the core passes through less dense and cooler layers in the photosphere, where atoms absorb some of the light.

Some of the hallmark lines to look for are the Hydrogen-alpha (Hα) line at 656.3 nanometers (nm), the sodium (Na) doublet at 589.3nm, and the Calcium (Ca) H and K lines at 396.9nm and 393.3nm. All of those lines were easy to observe and quite dark, especially the sodium doublet. The adjustment level on the side of the Lhires Lite allowed me to easily dial in any part of the solar spectrum.

Be certain you check the focus. If the Lhires Lite is out of focus, you will see color but no Fraunhöfer lines. A simple helical focuser does the job. The lines appear sharp and distinct when you've achieved the proper setting.

I did try other 1¼" eyepieces, including an 8-to-24mm zoom eyepiece; all worked well. The package I tested also included a 1.5x piggyback Barlow, which threads into the supplied eyepiece.

I also attempted to take some photos through the Lhires Lite at prime focus with my Canon EOS 10D digital SLR. Unfortunately, the focuser on the spectroscope would not rack in enough to allow me to achieve focus. Other cameras may work, however.

During one of my test sessions, I used the Lhires Lite for more than 2 hours on an 85° Fahrenheit (29.4° Celsius) day. I wanted to see if the instrument overheated or if the image changed dramatically. Although the Lhires Lite was warm to the touch (it is black), I noted no changes in image quality.

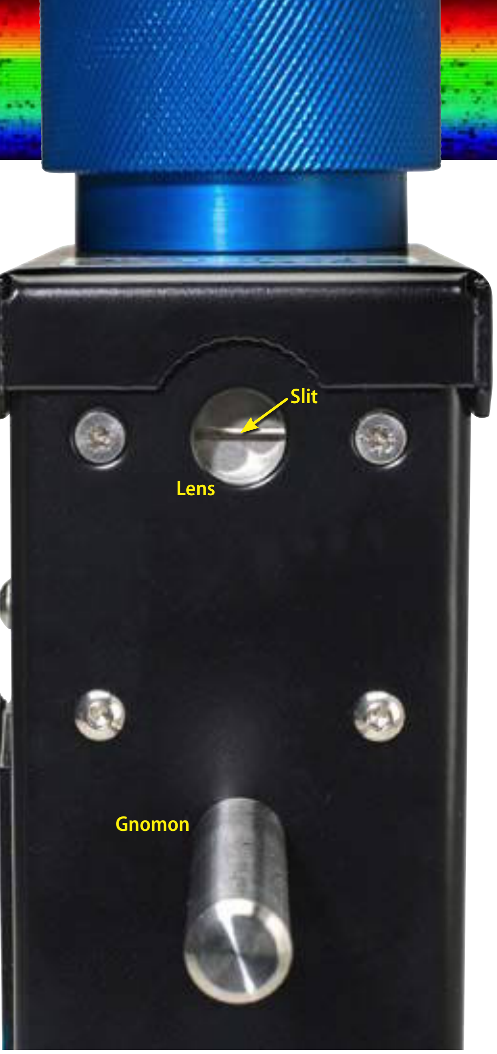
Specifications

Lhires Lite spectroscope

Type: Littrow high-resolution spectroscope
Grating: 2,400 grooves per millimeter
Focal ratio: f/50
Mount: ¼-20 thread for a camera tripod
Range: Full visible spectrum
Eyepieces: Accepts standard 1¼" eyepieces
Included: 25mm Plössl eyepiece, Barlow lens, custom-fitted aluminum case
Price: $1,395

Observing more than the Sun

I also used the Lhires Lite indoors, observing spectrum tubes. These tubes, filled with specific gases like hydrogen, helium, and carbon dioxide, are "lit" with a power supply and produce spectral lines by emission. Such lines lie in the same places on the spectrum as absorption lines, but they appear bright. It is easy to show bright spectral lines indoors and then take the Lhires Lite outdoors to observe the corresponding solar absorption lines. This makes for a powerful demonstration as to how we know which elements make up stars.



The aluminum gnomon atop the spectroscope allows you to quickly align the unit with the Sun. The lens allows its light to enter.

The Lhires Lite is not for observing stars. You will need a more complex instrument for those observations. Shelyak does manufacture such an instrument: the Lhires III. But the Lhires Lite will allow you to explore the world of solar spectroscopy as well as spectrum tubes and everyday lights. You will be amazed at what you see, no matter how often you've observed the Sun.

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Secret Sky

by Stephen James O'Meara

Test your vision: The perigee Moon

Take advantage of January's lunar opportunities by locating these naked-eye features.

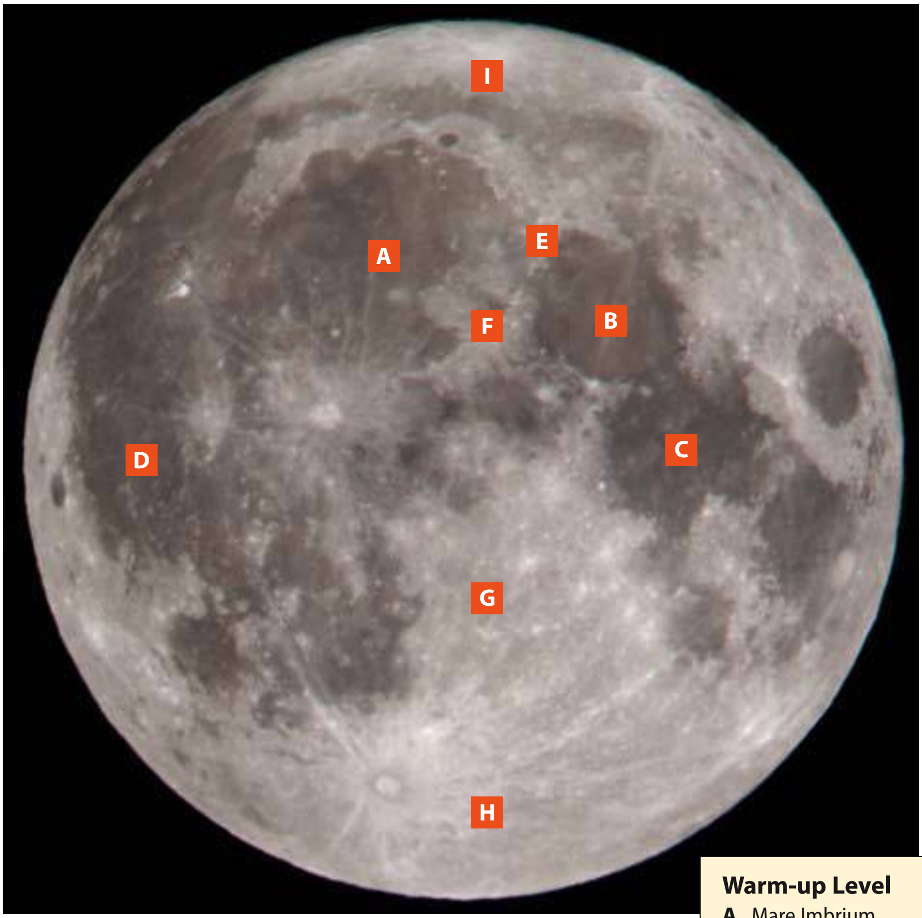
While looking at the Moon, have you ever wondered what the finest feature visible to the unaided eye might be? This month is a good time to find out because we have two Full Moons in a calendar month: on the evenings of December 31/January 1 and January 29/30. What's more, the Full Moons are also at "perigee" — the point in the Moon's orbit closest to Earth. Consequently, the Moon will appear larger than normal on those dates, allowing you to see it in finer detail.

In anticipation of these events, I formulated a fun way for you to test your visual acuity. Simply go outside during a Full Moon and try to see the various features labeled on the image on page 73; the smaller the number, the easier the feature is to see without optical aid. The degree of difficulty is based on my naked-eye studies dating from 1982 to the present. I've also divided the scale into four observing skill levels: (1) beginner, (2) intermediate, (3) advanced, and (4) expert. When referring to the locations of these features, I use the modern astronomical convention in which lunar north is up and west is to the left.

Warm-up exercises

Before starting the challenge, take time to "warm up" your vision. Any observer with average eyesight should be able to see the dark maria that make up the Man in the Moon: Mare Imbrium (A), the Man's right eye; Mare Serenitatis (B) and Mare Tranquillitatis (C), seen together as the Man's left eye; and Oceanus Procellarum (D), the Man's mouth. Resolving the Man's eyes requires seeing the bright Caucasus (E) and Apennine Mountains (F) as a string of light between them.

Browse the "Secret Sky" archive at www.Astronomy.com/OMeara.



To "warm up" your eyesight, try searching first for the obvious lunar features labeled here. Stephen James O'Meara

Warm-up Level

A	Mare Imbrium
B	Mare Serenitatis
C	Mare Tranquillitatis
D	Oceanus Procellarum
E	Caucasus Mountains
F	Apennine Mountains
G	Central Highlands
H	Southern Highlands
I	Northern Highlands

There's also a Woman in the Moon. Mare Serenitatis and Mare Tranquillitatis form the most obvious parts of her hair. The Moon's Central Highlands (G) outline her face and neck (seen in profile) while the Southern Highlands (H) mark her upper chest and shoulders.

If you can see those details with little effort, it's time to take the challenge.

Level 1 (beginner)

Our survey kicks off with an easy feature: Mare Crisium (1). This basalt plain appears as a dark stain in a bright highland region near the Moon's east-northeastern limb. In contrast, our second test object — the ejecta blanket surrounding the crater Copernicus (2) — looks like a bright stain collared by darkness just west of the Woman's face.

Now look for the highland region around Rimae Gutenberg (3) and its southeastern stem — commonly depicted as a hibiscus flower in the Woman's hair. To see it, you'll need to resolve Mare

Fecunditatis (4) to the northeast and Mare Nectaris (5) to the southwest, both extensions of the Woman's hair.

Level 2 (intermediate)

Return your gaze to Copernicus, then stare directly to its west for the small, bright region surrounding the crater Kepler (6). To its south, you'll find a bright spur jutting from the western side of the Southern Highlands into Oceanus Procellarum around the crater Gassendi (7). The dark form of Mare Humorum (8) abuts it to the southeast.

Cassini's Bright Spot (9) lies in the southwestern portion of the Woman's neck, near her collarbone — a naked-eye pearl in a necklace of lunar rays extending from the crater Tycho (invisible to the naked eye). Then look at the Moon's Northern Highlands (I) for the soft-gray shading of Mare Frigoris (10).

Level 3 (advanced)

Next look toward the northern Central Highlands for two small dark areas: Sinus Medii (11), the Woman's mouth; and Mare Vaporum (12), her eye. Immediately southwest of the Woman's chin is a long island of highland material extending northward from the Fra Mauro region (13).

The Aristarchus ejecta blanket (14) should appear as a fleck of light in Oceanus Procellarum, near the Moon's northwestern limb. And the Agatharchides region (15), which forms the pale northeastern border of Mare Humorum, provides a worthy challenge in visual contrast.

Level 4 (expert)

Expert observers — those who know the importance of patience and how to use their direct (not averted) vision — will have fun searching out these last five eye-rubbing details.

First up is the bright Archimedes Mountain range (16) northwest of the Apennines, followed by the dark divide between the Caucasus and Apennine mountain chains (17).

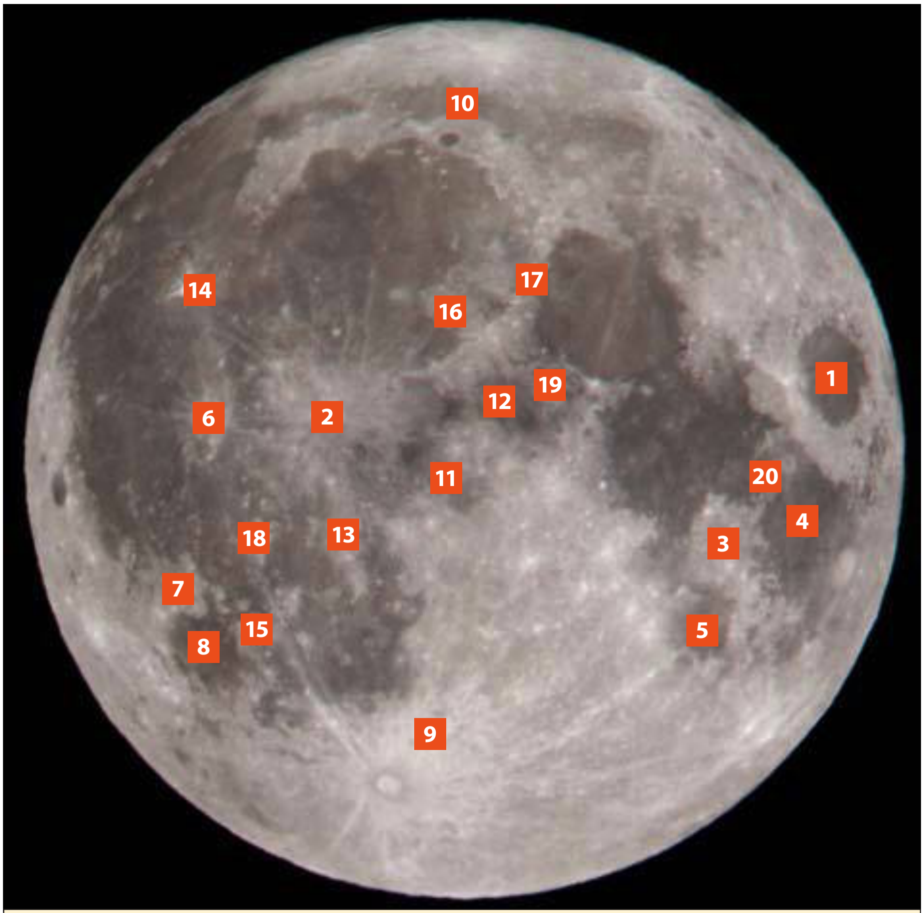
The Riphaeus Mountains (18) appear as a little glint of light midway between Copernicus and Mare Humorum, just west of the Fra Mauro region. The bright skirt around the crater Manilius (19) is an even smaller speck, shining east and slightly north of Mare Vaporum. Finally, the Superman/Superwoman Award goes to anyone who can see the Secchi Mountains (20) separating Mare Tranquillitatis from Mare Fecunditatis.

Some hints

While Full Moon and lunar perigee occur together this month, the Moon remains reasonably large and bright for a few days before and after this time, too. Also try looking for these features as the Moon waxes and wanes because shadowing effects may help increase the contrast between these features and their surroundings.

Don't let the high contrast between the light and dark markings as seen here in the photos fool you; the visual contrast is much lower. If possible, try to observe the Moon during twilight, which reduces glare. If you must look at the Full Moon in darkness, try using lightly shaded sunglasses. Gently swaying your head back and forth while looking directly at specific features will also help. I've even found it useful to walk as I stared up (but do this only if you're on a flat surface with plenty of room to roam; I don't want you tripping or falling over unseen obstacles).

Finally, my scale is in no way absolute. Everyone perceives regions of light and dark differently. There is no right or wrong, just what you see. I'm interested in your opinions, especially how you might renumber the scale to fit your own experience. Send observations and comments to someara@interpac.net.



Stephen James O'Meara

Level 1
- **1** Mare Crisium
- **2** Copernicus region
- **3** Rimae Gutenberg
- **4** Mare Fecunditatis
- **5** Mare Nectaris

Level 2
- **6** Kepler region
- **7** Gassendi region
- **8** Mare Humorum
- **9** Cassini's Bright Spot
- **10** Mare Frigoris

Level 3
- **11** Sinus Medii
- **12** Mare Vaporum
- **13** Fra Mauro
- **14** Aristarchus region
- **15** Agatharchides region

Level 4
- **16** Archimedes Mountains
- **17** Dark divide between Caucasus and Apennine mountains
- **18** Riphaeus Mountains
- **19** Manilius region
- **20** Secchi Mountains

Test your visual acuity by picking out these lunar features; the higher the number, the more difficult the feature will be to detect.

Observing Basics

by Glenn Chaple

Screw-in solar filter hazards

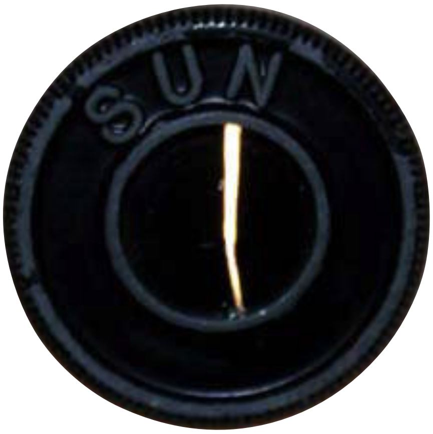
Readers provide firsthand evidence that these filters crack under the Sun's heat.

Last July, I asked readers to help me document the risk of using solar filters that screw into the eyepiece. These filters commonly came with low-budget telescopes made in the 1960s and 1970s. The telescopes were mostly 2.4-inch (60 millimeters) refractors or 4.5-inch (114mm) reflectors, the latter stopped down with 2-inch (50mm) aperture reducers. I used a screw-in Sun filter for 3 years safely, but quit when I read that they can crack after prolonged exposure to the Sun's concentrated heat. For decades I crusaded against screw-ins, warning people to avoid them at all cost. Yet I never heard of one actually failing, so I began to wonder if I might be passing along an urban (or, in this case, cosmic) legend. I wanted firsthand evidence.

I got the proof! Twenty e-mails arrived, each relating a horror story of screw-in Sun filters that shattered during use (read the reports at www.Astronomy.com/toc). Half of the victims were fortunate, either looking away at the time or surviving a mere hairline fracture of the filter.

The rest got a full dose of unfiltered sunlight. The scenario in these cases was similar — a cracking sound accompanied by a blinding flash of light, prompting the observer to recoil from the eyepiece. It is, as Russian amateur astronomer Oleg Pomogaev puts it, "a terrible feeling." For most, the ensuing "flashbulb" blindness was temporary.

Sherry Buttnor of the Royal Astronomical Society of Canada's Victoria Center wasn't so lucky. She writes: "I clearly remember hearing a faint creaking sound, then a startlingly loud crack as the solar filter split in two. I managed to look away, but not before seeing the blinding flash of the Sun. As with a camera flash, I had the after-image of the crack. But unlike the effects of a camera flash, I now have a scar on my retina. Twenty-seven years later, the scar affects the sight in that eye."



This screw-in solar filter cracked while Dennis O'Connell was turned away from the eyepiece of his secondhand 60-millimeter refractor some 40 years ago. Dennis O'Connell

Sherry wonders why a government agency in Canada or the United States never tested these screw-in Sun filters. Good question. If a wheel falls off a baby buggy, there's an immediate and total nationwide recall of all buggies in that particular make and model. I'm not aware of any recalls or bans, past or present, on screw-ins, despite their danger.

Northeast Florida Astronomical Society member Ted Treiber went the "Mythbuster" route, testing several screw-in Sun filters by placing each in a motor-driven 60mm refractor and waiting. He relates the following: "Sure enough, within 2 minutes that first filter gave a loud pop, and there was white light on the projection plate! A second filter lasted almost 4 minutes. A third didn't make it 2 minutes. All gave a loud pop when they went, and there were glass bits in front of the diagonal. Not good."

Need visual proof that screw-in Sun filters can crack during use? Dennis O'Connell, an adjunct instructor at Corning Community College in New York took the photograph on this page of a cracked screw-in. About 40 years ago, he was using that filter with a secondhand 60mm refractor. "I had just turned away from the eyepiece when it blew," O'Connell writes. "I kept the filter and display it each time I do a presentation on solar astronomy."

Tales of screw-in Sun filters shattering suddenly can no longer be considered the stuff of cosmic legend. Thanks to the evidence presented, warnings about these filters are the truth, the whole truth, and nothing but the truth. Case closed.

By the way, a lot of budget telescopes with screw-in Sun filters are still in circulation, many having been donated to public schools. If you have the opportunity to conduct a star party at a local school, warn the teachers about these filters, and urge them to get rid of any that might be on hand. Terry Durban, of Wever, Iowa, is on the mark when he says, "All of the screw-in Sun filters that still exist should be gathered up and buried in a deep, deep hole."

Remember, the safest way to view the Sun is by solar projection with a small-aperture telescope. If you want to view the Sun directly with a telescope, purchase a solar filter that fastens to the front of the tube. The Sun is a fascinating telescopic target, if you observe it safely!

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Special thanks to the readers who sent in e-mails regarding screw-in Sun filters. Next month: Digital astrophotography for dummies (including me). Clear skies!

Browse the "Observing Basics" archive at www.Astronomy.com/Chaple.

See reader reports of cracked screw-in Sun filters at www.Astronomy.com/toc.

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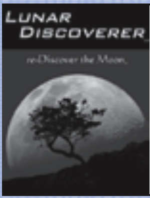

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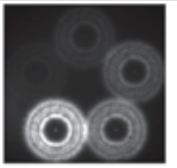

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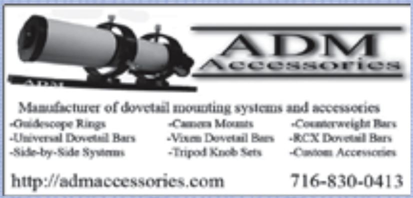
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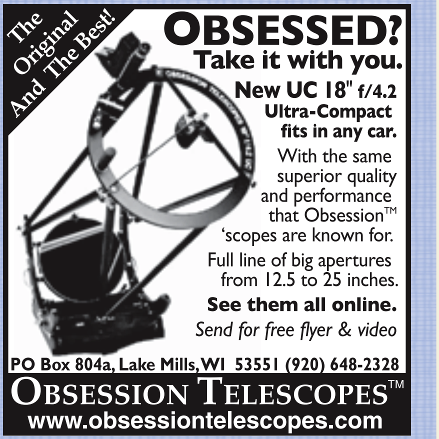
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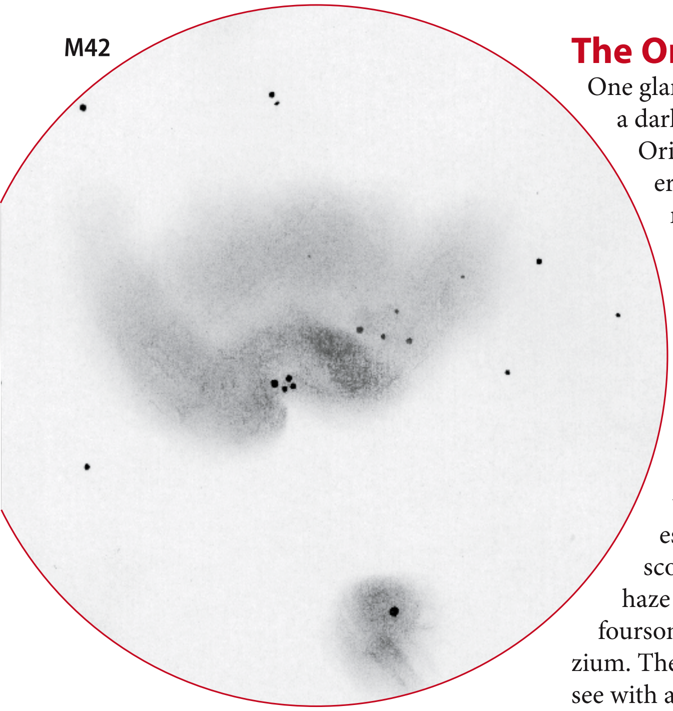
Deep-sky Showcase

The Orion Nebula and NGC 2158

Astronomy's editor sketches two of his favorite objects.

by David J. Eicher



The Orion Nebula sketched by David J. Eicher using an 8-inch f/10 SCT at 50x.

The Orion Nebula (M42)

One glance at the sword of Orion under a dark sky hints at the beauty of the Orion Nebula for backyard observers. Visible to the eye alone as a misty patch, the nebula comes alive in a telescope. Its brightness, large size (more than twice the diameter of the Full Moon), and curious shape make it a favorite nebula in the sky for many observers.

This huge star-forming region lies about 1,350 light-years away, making it the closest star factory to Earth. A small scope reveals a gauzy, gray-green haze of light centered on a bright foursome of stars known as the Trapezium. These stars are bright enough to see with any telescope and sparkle like diminutive jewels. A dark protuberance known as the "Fish's Mouth" cuts into the nebula near this point. To the south, graceful wings of nebulosity arc downward. Between them lies a bright body of nebulosity and scattered new stars that formed from the gas. Another bright nebula, the comma-shaped M43, lies just to the north. I think you'll agree that the Orion Nebula is one of the sky's greatest deep-sky objects.

M42

Jason Ware

Designations: M42, NGC 1976
Position: 5h35m, –5°23' (2000.0)
Constellation: Orion
Magnitude: 3.0
Size: 66' by 60'
Distance: 1,350 light-years

NGC 2158

Neil Jacobstein/Adam Block/NOAO/AURA/NSF

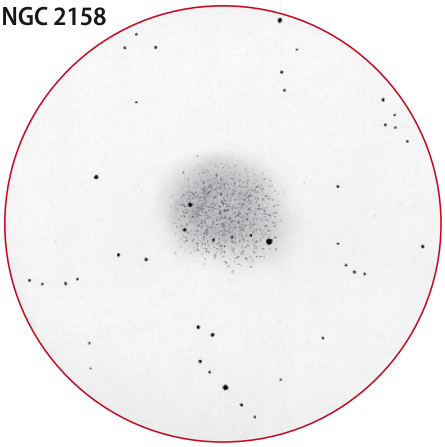
Designation: NGC 2158
Position: 6h07m, 24°06' (2000.0)
Constellation: Gemini
Magnitude: 8.6
Size: 5'
Distance: 1,500 light-years

David J. Eicher *is the editor of* Astronomy. *He has observed and sketched deep-sky objects for 33 years.*

Open cluster NGC 2158

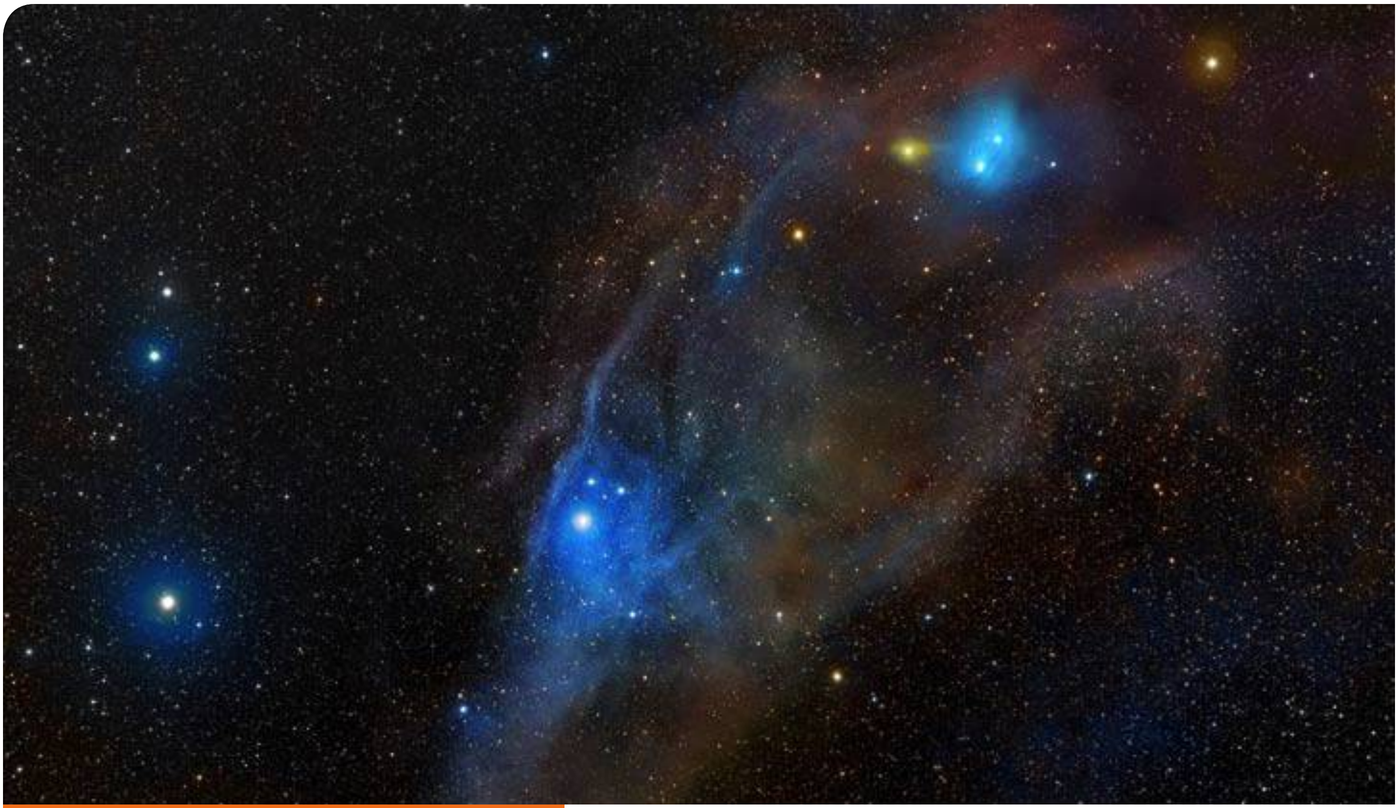
Another great showpiece of the winter sky, open cluster M35, lies near Orion in the constellation Gemini. This big, scattered group of 200 suns spanning an area as large as the Moon is easy to see with the naked eye on a dark night. I like M35 just fine, but one of my favorite open clusters is a smaller one visible on the southwestern edge of M35 — the diminutive group NGC 2158. While M35 is practically on our doorstep, just 270 light-years away, NGC 2158 is a similar object that floats in a galactic arm some 5½ times more distant. So the two make an interesting contrast in the same binocular field of view.

A small telescope shows NGC 2158 as a rich haze of light from countless unresolved stars, peppered by numerous faint suns floating in front. A few bright stars lie scattered around the cluster's apparent edges. This makes for a glorious sight, one of the best telescopic fields of the winter Milky Way!



NGC 2158 sketched by David J. Eicher using an 8-inch f/10 SCT at 70x.

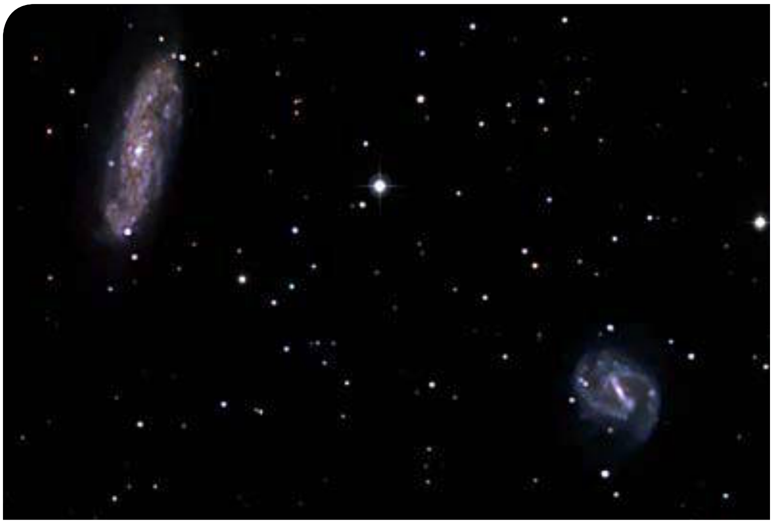
reader gallery



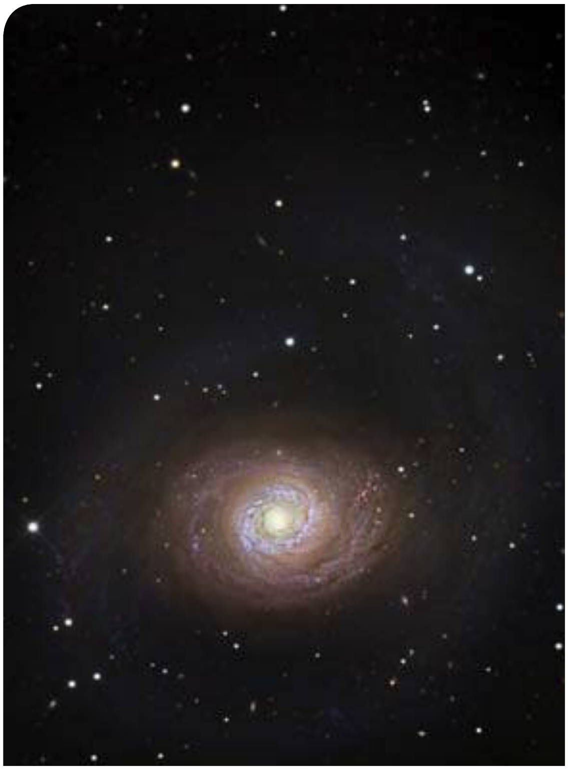
The Blue Horsehead (4-inch Takahashi FSQ-106 at f/3.6, SBIG STL-11000 CCD camera, LRGB/Hα image with exposures of 200, 40, 40, 40, and 45 minutes, respectively)
• Rogelio Bernal Andreo, Sunnyvale, California

A horse of a different color

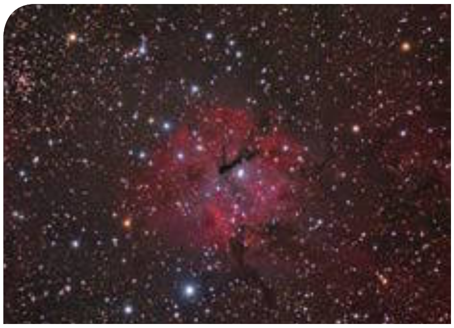
Scorpius the Scorpion holds many deep-sky surprises for observers and imagers. One is IC 4592, which amateur astronomers sometimes call the Blue Horsehead, but only when they see it as part of a wide-field image. This spectacular region of reflection nebulosity mirrors and scatters the light from the brightest component of the nearby multiple star Jabbah (Nu [ν] Scorpii). That star lies at the horse's "eye," near the center of this image. Although much dark dust lies in this area, the nebula's main color is blue because blue light scatters most.



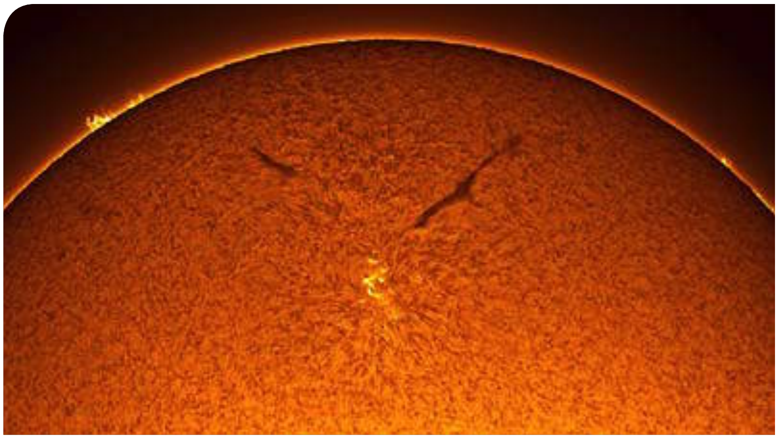
NGC 3511 and NGC 3513 in the constellation Crater are the same type of spiral galaxies. Because NGC 3511 (left) inclines more to our view, we see the galaxy's stars through more of its dust, so it appears reddened compared to NGC 3513. (12.5-inch Optical Guidance Systems Ritchey-Chrétien telescope at f/9, SBIG ST-10XE CCD camera, LRGB image with exposures of 300, 50, 50, and 50 minutes, respectively)
• Ted Wolfe, Naples, Florida



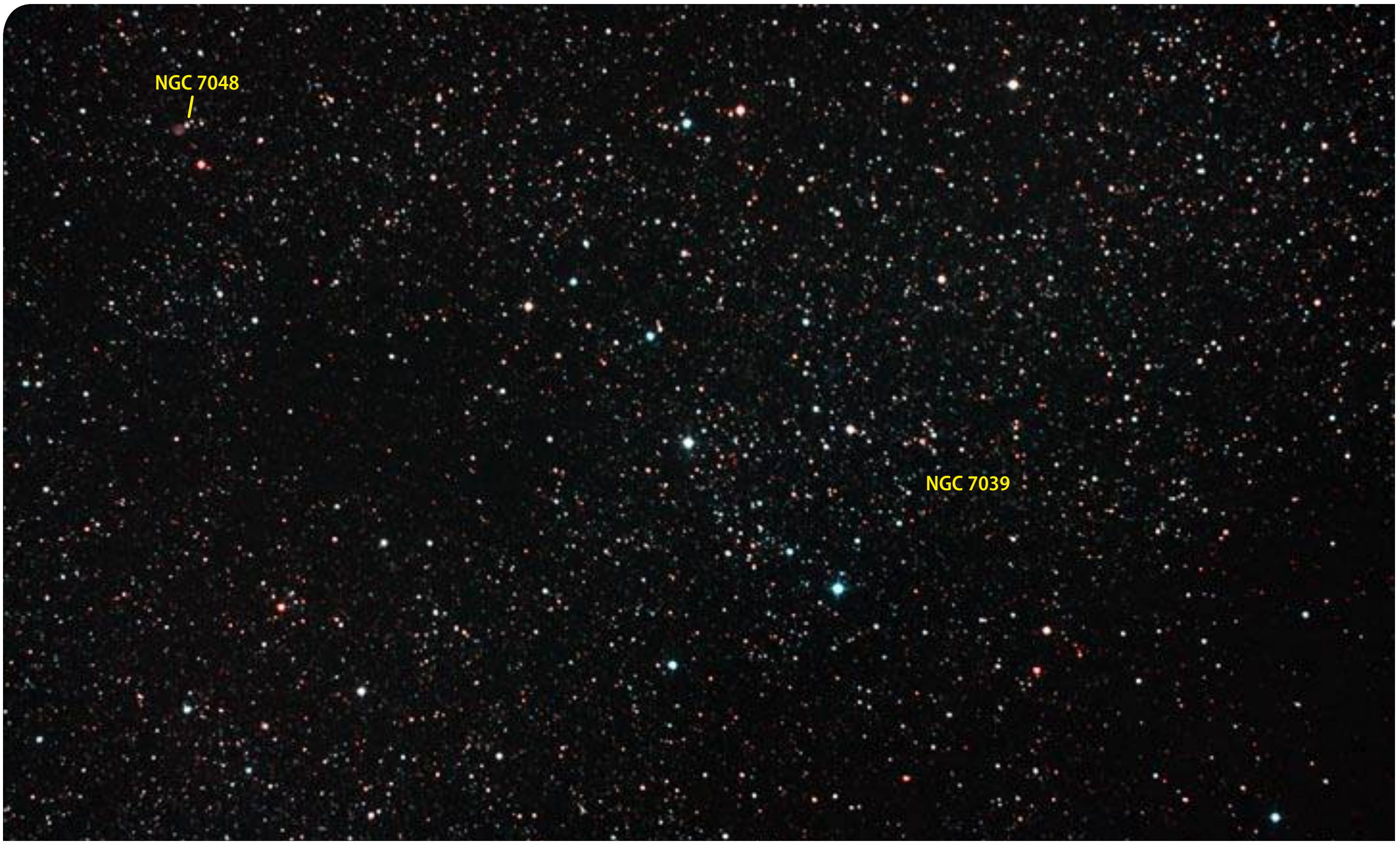
Spiral galaxy M94 in Canes Venatici is a dusty galaxy with a bright inner ring that blazes with the light of millions of stars. Spiral arms wind tightly around the core. (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8, SBIG STL-11000 CCD camera, LRGB image with exposures of 550, 90, 54, and 108 minutes, respectively) • R. Jay GaBany, San Jose, California



<**Gum 15** in Vela is the 15th entry in a catalog of 85 emission nebulae visible in the Southern Hemisphere compiled by Australian astronomer Colin Stanley Gum. (4-inch Takahashi FSQ-106N refractor at f/5, Starlight Xpress SXVF-M25C CCD camera, twelve 10-minute exposures, stacked) • Louie Atalasidis, Coonabarabran, Australia



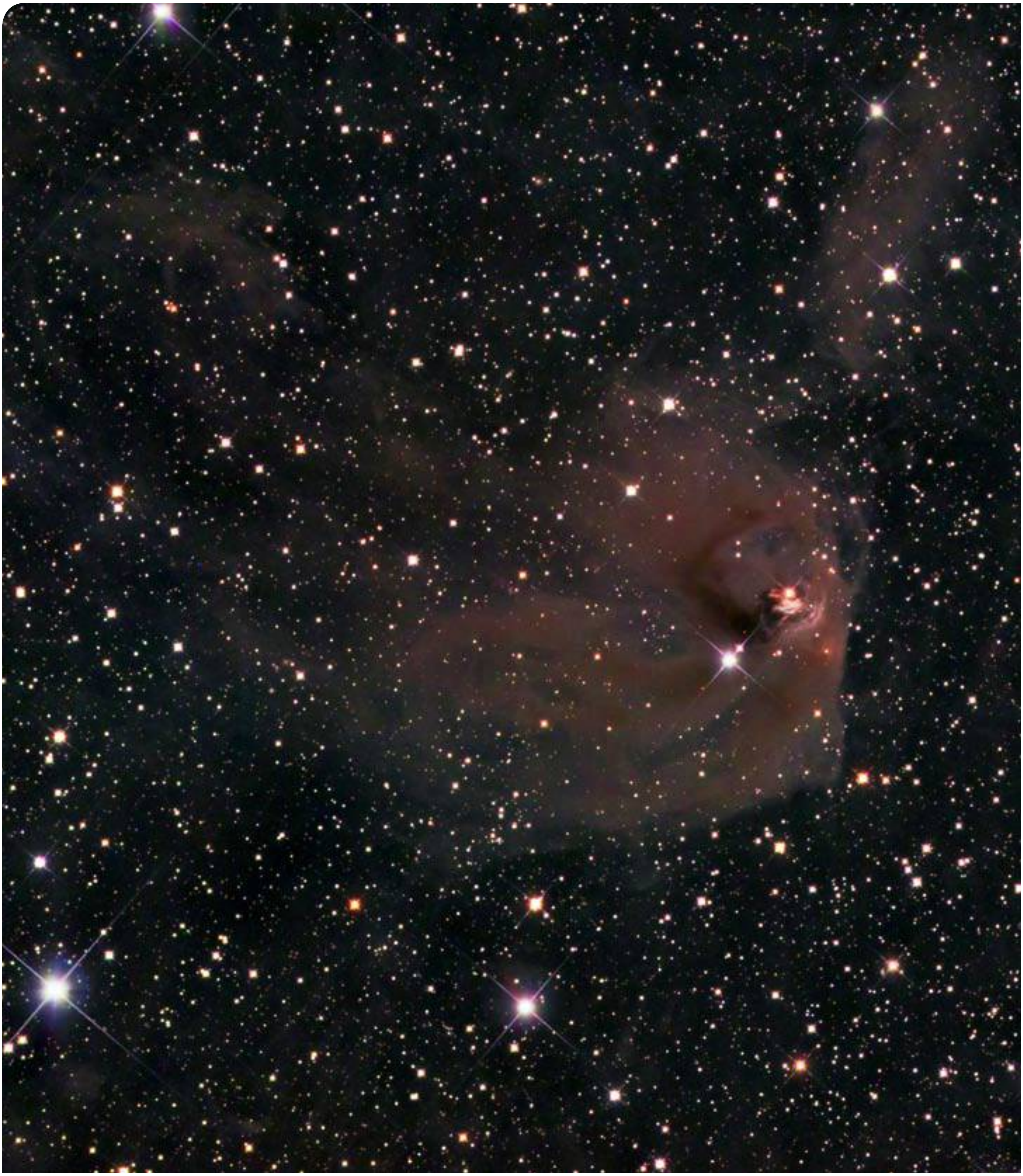
Two dark filaments accompany a large sunspot (marked by bright flare regions) in this Hydrogen-alpha image. Several prominences also crest above the Sun's limb. (Coronado SolarMax 90 Hydrogen-alpha telescope at f/10, Lumenera SKYnyx 2-2 monochromatic CCD camera, four frames combined out of a total of 150, taken April 6, 2006, at 14h00m UT) • Greg Piepol, Rockville, Maryland



Open cluster NGC 7039 in Cygnus, which shines at magnitude 7.6, lies near another deep-sky treat: magnitude 11.0 planetary nebula NGC 7048. (5-inch homemade Newtonian reflector, Canon XSi digital SLR, ISO 800, 25-minute exposure) • John Chumack, Dayton, Ohio

reader gallery

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, and exposure information. Submit images by e-mail to readergallery@Astronomy.com.



Hind's Variable Nebula (NGC 1555) sits in a vast cloud of dust just north of the Hyades in Taurus. The bright star to the lower left of the central dusty region is the variable T Tauri, which usually shines at magnitude 9.6. (Luminance data acquired with a 12-inch Astro Systeme Austria N12 astrograph at f/3.5 and an SBIG STL-11000M CCD camera; combined with RGB data from a 5-inch Tele Vue 127is refractor at f/5.4 and an FLI MicroLine CCD camera, LRGB image with exposures of 250, 100, 100, and 100 minutes, respectively) • Thomas V. Davis, Inkom, Idaho

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Astronomy's 2010 Guide to the Night Sky

LUNAR PHASES

New	First	Full	Last
			Jan. 7
Jan. 15	Jan. 23	Jan. 30	Feb. 5
Feb. 13	Feb. 21	Feb. 28	March 7
March 15	March 23	March 29	April 6
April 14	April 21	April 28	May 6
May 13	May 20	May 27	June 4
June 12	June 19	June 26	July 4
July 11	July 18	July 25	Aug. 3
Aug. 9	Aug. 16	Aug. 24	Sept. 1
Sept. 8	Sept. 15	Sept. 23	Sept. 30
Oct. 7	Oct. 14	Oct. 22	Oct. 30
Nov. 6	Nov. 13	Nov. 21	Nov. 28
Dec. 5	Dec. 13	Dec. 21	Dec. 27

All dates are for the Eastern time zone. A Full Moon rises at sunset and remains visible all night; a New Moon crosses the sky with the Sun and can't be seen.

THE MOON is Earth's nearest neighbor and the only celestial object humans have visited. Because of its changing position relative to the Sun and Earth, the Moon appears to go through phases, from a slender crescent to Full Moon and back. The best time to observe the Moon through a telescope comes a few days on either side of its two quarter-phases. For the best detail, look along the terminator — the line separating the sunlit and dark parts. NASA

MARS shines big and bright early in 2010. The Red Planet rises shortly after sunset at the beginning of the year. It peaks at opposition in late January, when it stays out all night. Mars remains visible during the evening until early December. When viewed through a telescope, the planet's icy north polar cap should stand out. Other features, such as dusky plateaus, are harder to see but show up as contrasting shades of orange and brown. Also watch as Mars passes just north of the Beehive star cluster (M44) in mid-April. HST

JUPITER always shows a dynamic face. Its atmosphere displays an alternating series of dark belts and brighter zones pocked by the Great Red Spot. Even through a small telescope, the planet's four biggest moons — Io, Europa, Ganymede, and Callisto — appear conspicuous. You may see dramatic movement of these bright moons during the course of a single night. Jupiter reaches its peak in September, when it shines brightest and looms largest, although it's a fine sight from March until year's end. NASA/JPL/SSI

SATURN may be the ringed planet, but it doesn't look like one for much of this year. The rings tilt only a few degrees to our line of sight until autumn. Saturn appears brightest at opposition in March, when the rings tilt just 3°. But by the end of 2010, the tilt increases to 10°. That's the best time to view the rings through a telescope, which will reveal the broad Cassini Division that separates the two bright rings. Also watch for Saturn's biggest moon, 8th-magnitude Titan. HST

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A supplement to *Astronomy* magazine

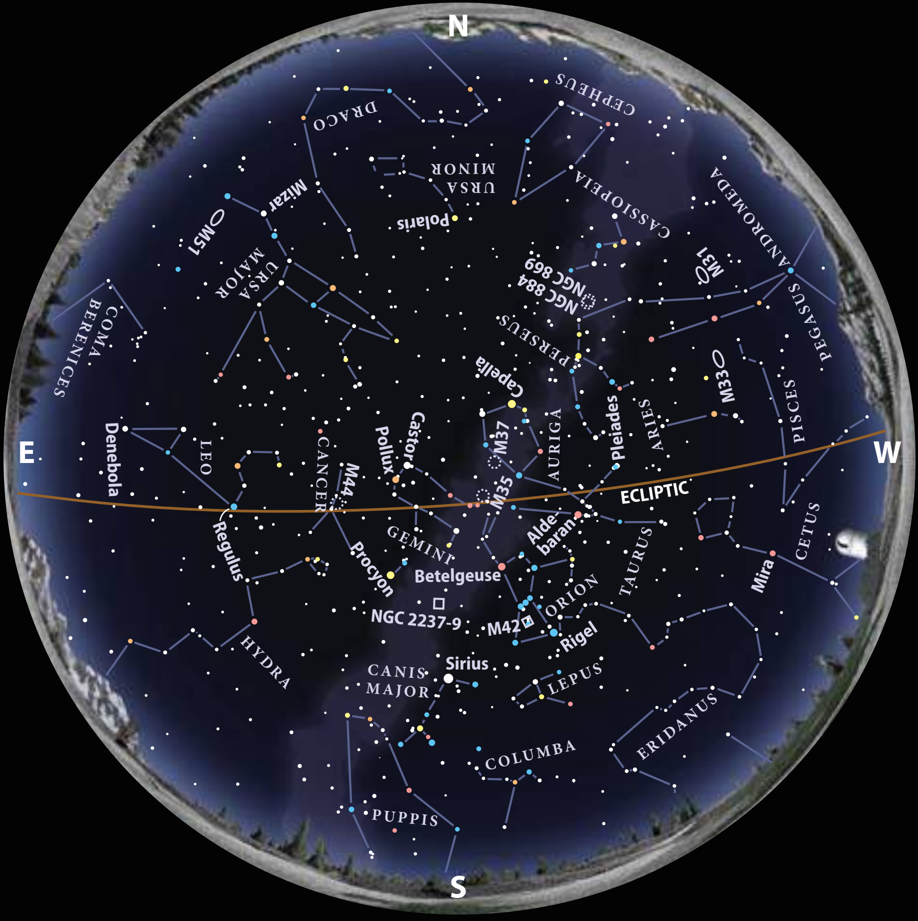
WINTER

The sky

Winter boasts the brightest stars of any season. Orion the Hunter dominates the evening sky this time of year. Its seven brightest stars form a distinctive hourglass pattern. The bright blue star marking Orion's left foot is Rigel, and the ruddy gem at his right shoulder is Betelgeuse. The three stars of the Hunter's belt point down to Sirius, the brightest star in the night sky, and up to Aldebaran, the eye of Taurus the Bull. Above Orion lies the constellation Gemini the Twins.

Deep-sky highlights

The Pleiades (M45) is the brightest star cluster in the sky. It looks like a small dipper, but it is not the Little Dipper.
The Orion Nebula (M42), a region of active star formation, is one of the showpieces through telescopes of all sizes.
The Rosette Nebula (NGC 2237–9), located 10° east of Betelgeuse, presents an impressive cluster of stars and a gaseous nebula.
M35 in Gemini the Twins is a pretty open cluster, best viewed with a telescope.
Castor in Gemini is easy to split into two components with a small telescope, but the system actually consists of six stars.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CETUS
Mira
Regulus
Procyon
Betelgeuse
NGC 2237-9
M42
ORION
Rigel
Sirius
CANIS MAJOR
LEPUS
HYDRA
ERIDANUS
COLUMBA
PUPPIS

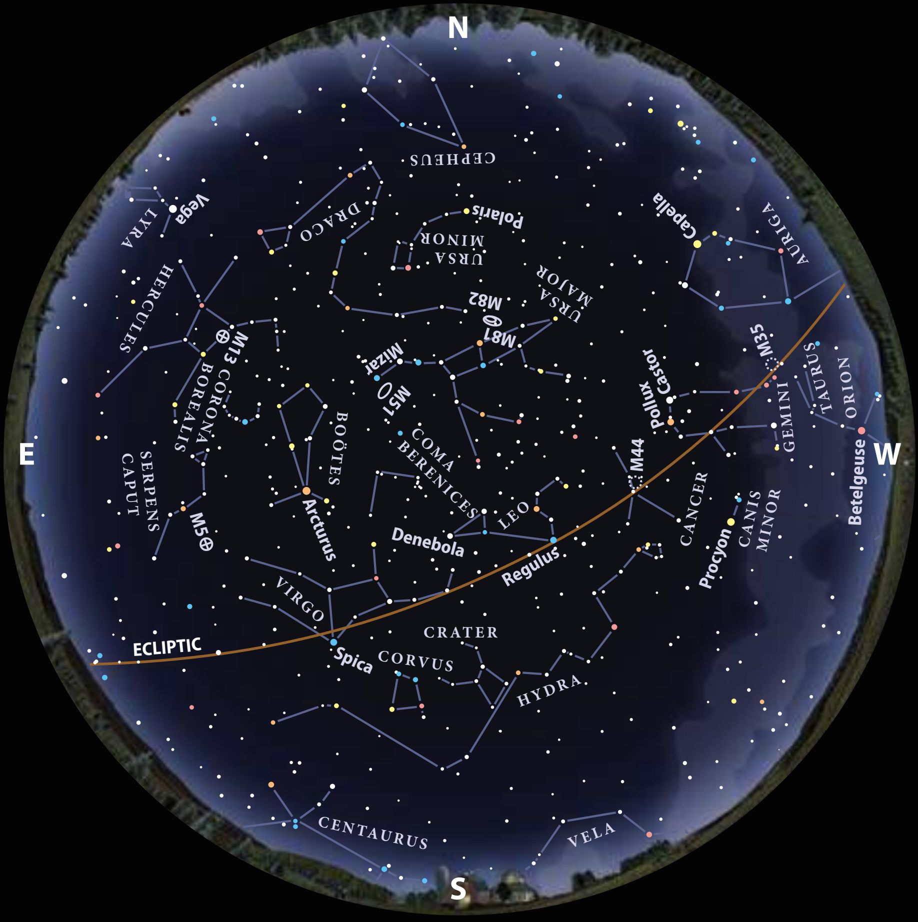
SPRING

The sky

The Big Dipper, the most conspicuous part of the constellation Ursa Major the Great Bear, now rides high in the sky. Poke a hole in the bottom of the Dipper's bowl and the water would fall on the back of Leo the Lion. The two stars at the end of the bowl, called the Pointer Stars, lead you directly to Polaris, the North Star. From the bowl's top, simply go 5 times the distance between the Pointers. Spring is the best time of year to observe a multitude of galaxies. Many of these far-flung island universes, containing hundreds of billions of stars, congregate in northern Virgo and Coma Berenices.

Deep-sky highlights

The Beehive Cluster (M44) was used to forecast weather in antiquity. It is a naked-eye object under a clear, dark sky, but it disappears under less optimal conditions.
M5, a conspicuous globular cluster, lies between the figures of Virgo the Maiden and Serpens Caput the Serpent's Head.
The Whirlpool Galaxy (M51) is a vast spiral about 30 million light-years away.
M81 and **M82** in Ursa Major form a pair of galaxies that can be spotted through a low-power eyepiece.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VIRGO
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Spica
CRATER
CORVUS
HYDRA
CENTAURUS
VELA

Star maps by *Astronomy*: Roen Kelly

2010 EVENTS

Jan. 15 Annular solar eclipse (Africa, southern and eastern Asia)

Jan. 26 Mercury is at greatest western elongation

Jan. 29 Mars is at opposition

Feb. 18 Asteroid Vesta is at opposition

March 21 Saturn is at opposition

April 8 Mercury is at greatest eastern elongation

April 22 Lyrid meteor shower peaks

June 18 Asteroid Ceres is at opposition

June 25 Pluto is at opposition

June 26 Partial lunar eclipse

July 11 Total solar eclipse (South Pacific and South America)

Aug. 12 Perseid meteor shower peaks

Aug. 19 Venus is at greatest eastern elongation

Aug. 20 Neptune is at opposition

Sept. 19 Mercury is at greatest western elongation

Sept. 21 Jupiter is at opposition

Sept. 21 Uranus is at opposition

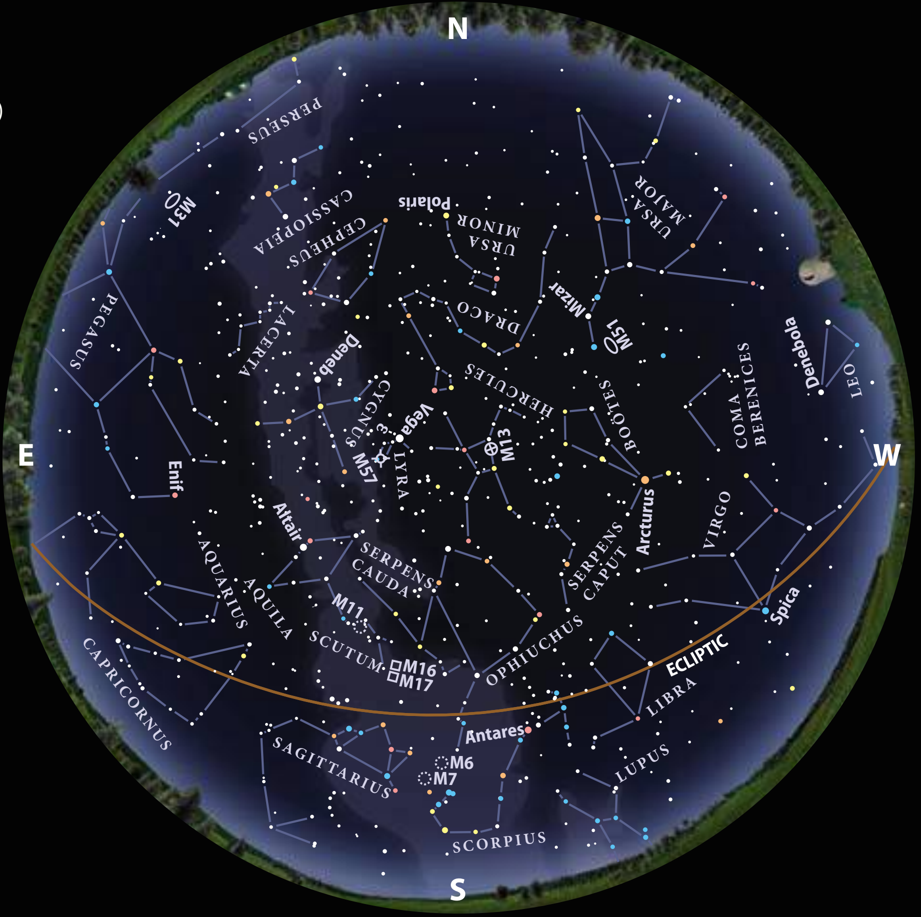
Sept. 23 Venus shines brightest in the evening sky

Dec. 4 Venus shines brightest in the morning sky

Dec. 14 Geminid meteor shower peaks

Dec. 21 Total lunar eclipse

⁙	Open cluster
⊕	Globular cluster
□	Diffuse nebula
⌾	Planetary nebula
⬭	Galaxy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PEGASUS
LACERTA
Deneb
CYGNUS
Vega
LYRA
M57
HERCULES
M13
BOÖTES
COMA BERENICES
Denebola
LEO
Enif
Altair
AQUILA
SERPENS CAUDA
SERPENS CAPUT
Arcturus
VIRGO
Spica
AQUARIUS
M11
SCUTUM
M16
M17
OPHIUCHUS
ECLIPTIC
LIBRA
CAPRICORNUS
Antares
M6
M7
SAGITTARIUS
SCORPIUS
LUPUS

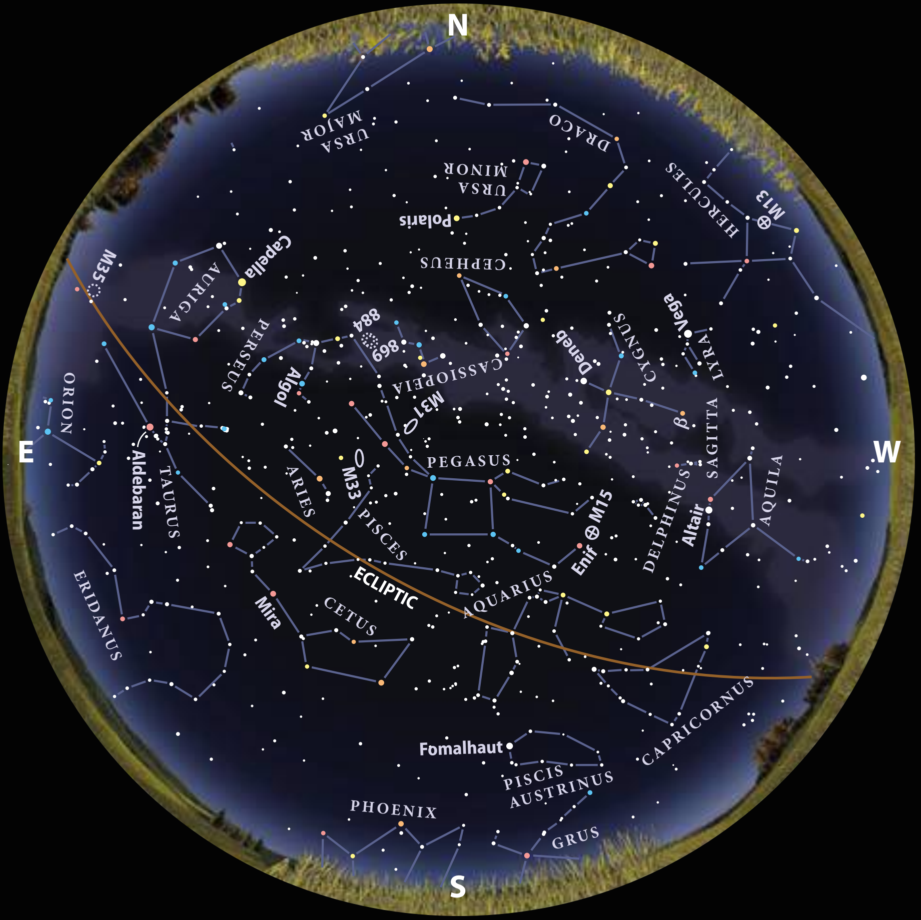
SUMMER

The sky

High in the sky, the three bright stars known as the Summer Triangle are easy to spot. These luminaries — Vega in Lyra, Deneb in Cygnus, and Altair in Aquila — lie near the starry path of the Milky Way. Following the Milky Way south from Cygnus, we find the center of our galaxy in the constellation Sagittarius the Archer. Here, you will find countless star clusters and glowing gas clouds. Just west of Sagittarius lies Scorpius the Scorpion, which contains the red supergiant star Antares as well as M6 and M7, two brilliant clusters that look marvelous at low power.

Deep-sky highlights

The Hercules Cluster (M13) contains nearly a million stars and is the finest globular cluster in the northern sky.
The Ring Nebula (M57) looks like a puff of smoke through a medium-sized telescope.
The Omega Nebula (M17) looks like the Greek letter of its name through a telescope at low power. This nebula also is called the Swan.
The Wild Duck Cluster (M11) is a glorious open star cluster. On a moonless night, a scope will show you more than 50 stars.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CYGNUS
Vega
LYRA
ORION
Aldebaran
TAURUS
ARIES
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PEGASUS
PISCES
M15
Enif
DELPHINUS
SAGITTA
Altair
AQUILA
ERIDANUS
Mira
CETUS
ECLIPTIC
AQUARIUS
CAPRICORNUS
Fomalhaut
PISCIS AUSTRINUS
PHOENIX
GRUS

AUTUMN

The sky

The Big Dipper swings low this season, and from parts of the southern United States, it even sets. With the coming of cooler nights, Pegasus the Winged Horse rides high in the sky as the rich summer Milky Way descends in the west. Fomalhaut, a solitary bright star, lies low in the south. The magnificent Andromeda Galaxy reaches its peak nearly overhead on autumn evenings, as does the famous Double Cluster. Both of these objects appear as fuzzy patches to the naked eye under a dark sky.

Deep-sky highlights

The Andromeda Galaxy (M31) is the brightest naked-eye object outside our own galaxy visible in the northern sky.
The Double Cluster (NGC 869 and NGC 884) in Perseus consists of twin open star clusters. It's a great sight through binoculars.
M15 in Pegasus is a globular cluster containing hundreds of thousands of stars, many of which can be glimpsed with a medium-sized telescope.
Albireo (Beta [β] Cygni), the most beautiful double star in the sky, is made up of stars colored sapphire and gold.

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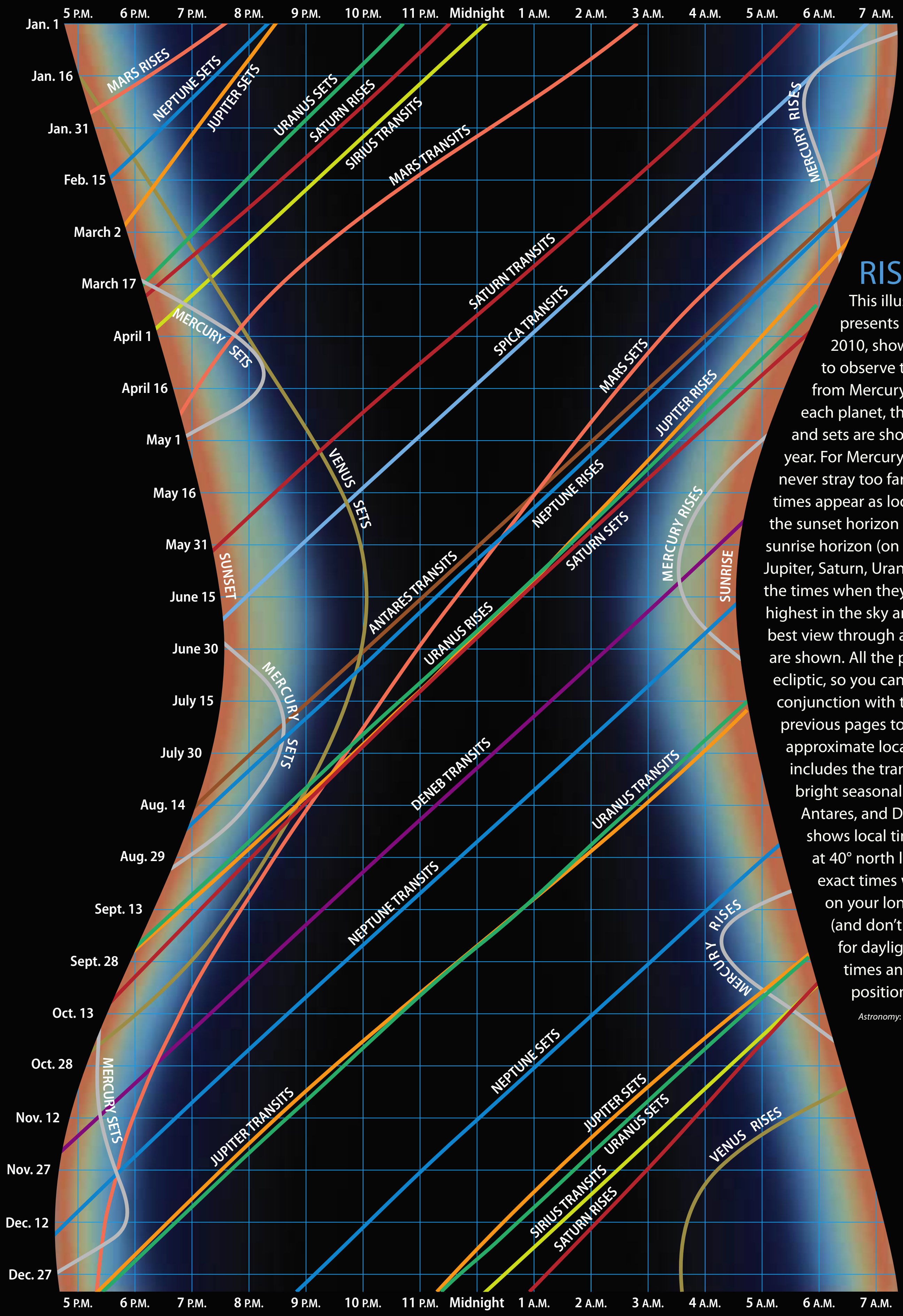

RISE & SET

This illustration graphically presents the night sky for 2010, showing the best times to observe the major planets, from Mercury to Neptune. For each planet, the times when it rises and sets are shown throughout the year. For Mercury and Venus, which never stray too far from the Sun, these times appear as loops coming up from the sunset horizon (on the left) or the sunrise horizon (on the right). For Mars, Jupiter, Saturn, Uranus, and Neptune, the times when they transit — appear highest in the sky and provide the best view through a telescope — also are shown. All the planets lie near the ecliptic, so you can use this chart in conjunction with the maps on the previous pages to find a planet's approximate location. The chart also includes the transit times of four bright seasonal stars: Sirius, Spica, Antares, and Deneb. This map shows local times for an observer at 40° north latitude. Although exact times will vary depending on your longitude and latitude (and don't forget to add 1 hour for daylight time), the relative times and approximate positions will stay the same.

Astronomy: Rick Johnson